European Commission

European Construction Sector Observatory

Digitalisation in the construction sector

Analytical Report

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DISCLAIMER

Table of Contents

Table of Figures

Table of Tables

Table of Boxes

Executive Summary

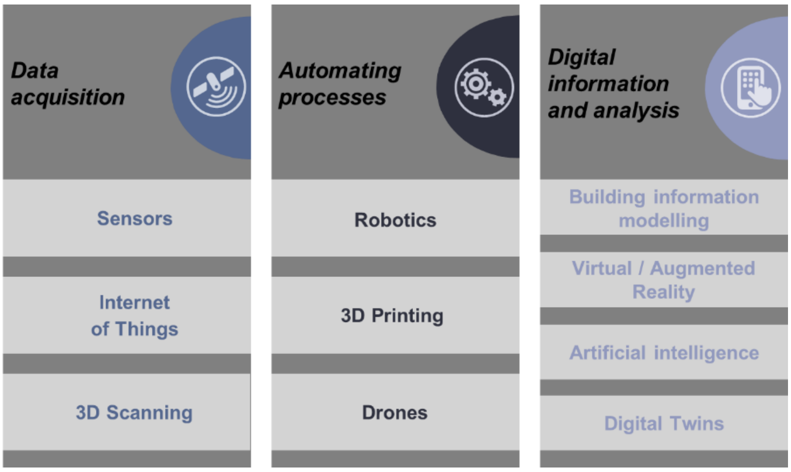
This Analytical Report is part of the European Construction Sector Observatory (ECSO) project. It aims to describe the state of play of digitalisation in the EU construction sector and identify some of its main drivers and challenges. In doing so, the report provides information, evidence and lessons learnt aiming to support a wide range of stakeholders, including policymakers, who wish to support the integration of digital technologies in the construction sector.

Though transforming, the construction sector is one of the least digitalised sectors in the economy. At the same time, the integration of digital technologies is often viewed as a key element to tackle some of the main challenges it is faced with, such as labour shortage, competitiveness, resource and energy efficiency, and productivity.

State of play of digitalisation in the construction sector

This Report presents the state of play of the most relevant digital technologies in the construction sector. Very different levels of maturity and adoption were identified, both among EU Member States, among different technologies and even among different phases of the same construction process. Nonetheless, what has clearly emerged is that the EU construction sector is making progress in the uptake of digital technologies.

The market analysis showed that among data acquisition technologies, sensors are the technology with the highest level of market maturity and technological readiness; however, significant margins of improvement are present when it comes to their integration in existing buildings. 3D scanning is being increasingly used, while IoT is not yet widely adopted, although it is developing rapidly.



Automating processes in the construction sector refer to the use of robots, 3D printing and drones to automate specific tasks in the construction sector. These technologies differ significantly in terms of development. Drones are being increasingly used, notably through the development and improvement of the sensors that they are equipped with, while robots and 3D printing are still at the development phase and utilised only for very specific and limited tasks. The low market readiness of automating technologies reflects also the fact that the construction and maintenance phases of the value chain have more limited traction when it comes to digitalisation.

The EU construction sector is making progress in the uptake of digital technologies

Last, the effective use of digital data represents the future of the digitalisation of the construction sector. In fact, data analysis is needed to give a meaning to all the data gathered and deliver tangible improvements and benefits. However, as the technologies and innovations in this category are deeply connected to the maturity of the data acquisition and automation technologies, their status varies significantly from one to the other. Building Information Modelling

(BIM) is more and more utilised in the construction sector; however, it is often limited to the design phase of (large) projects. Virtual and Augmented reality and Artificial Intelligence are still at development stages and cannot yet be considered as market ready. Digital Twins are for the moment limited to a few pilot projects, but the majority of public and private stakeholders consulted agrees that they have high potential for the future.

Digitalisation policies and initiatives in the EU

There is strong interest among policymakers to support the digitalisation of the construction sector. In the majority of EU Member States – 16 out of 27 – there are in place policies covering or specifically targeting the digitalisation of the construction sector. Policy measures in support of digitalisation are often accompanied by financial support in the form of grants, loans or equity, but also by technical assistance, such as for digital construction platforms. Digital construction platforms are a successful example of public policy analysed. These platforms are virtual or physical spaces gathering private and public stakeholders to support the integration of digital technologies. While platforms do not always generate strong traction, they enable collaborations, synergies and knowledge sharing within the construction sector and between the public and the private sector.

Many national governments have in place BIM requirements in their public procurement processes. Feedback from both the industry and public sector actors consulted for this report indicates that this is particularly beneficial for fostering the digitalisation of the construction sector. However, in developing such requirements, public sector actors also need to i) build their BIM related capacities; ii) balance their focus between low price and high quality; iii) and make sure that all types of companies (small and large) can leverage on these opportunities to digitalise.

National and local governments also facilitate the uptake of digital technologies in the construction sector by providing e-services, such as by issuing building permits and keeping the repository of building data and geospatial information (cadastre). These provide crucial information and data and could facilitate the uptake of digital technologies. In this regard, an increasing number of EU Member States have adopted digital building permits systems, digital logbooks, and registries of properties. Their level of sophistication is evolving as well, with e.g. the inclusion of Geographic Information System (GIS) and 3D models for digital registry of properties. Overall, with the recent development at the EU level – in terms of policies, support measures, funding, etc. - it can be expected that national governments will be incentivised to do more to support to the digitalisation of their construction sector. This will be crucial for supporting the transformation of the sector and its growth, but also to reach climate and sustainability related objectives.

Drivers and challenges of digitalisation in the construction sector

Drivers

Both policy and market drivers play a key role in the digitalisation of the construction sector. The European Commission has put in place ambitious policies to support the uptake of digital technologies within the EU. The Renovation Wave aims to at least double renovation rates across the EU in the next ten years; the Directive on the Energy Performance of Buildings also promotes smart technologies; and the European Green Deal dedicates a specific attention to the circularity of the construction sector. These policies are coupled with funding such as the Horizon Europe and Digital Europe programmes, the Recovery and Resilience Facility, and InvestEU.

The Renovation Wave aims to at least double renovation rates across the EU in the next ten years

The main market drivers are companies' needs to improve productivity and cut costs, and market demand in the uptake of digital technologies, which push construction tech companies to innovate.

Challenges

The analysis concluded that the cost of equipment and software, lack of skilled workforce, and lack of awareness and understanding of digital technologies are the three main factors hindering the faster and broader digitalisation of the European construction sector. That being said, significant variations are present across MS, technologies, and actors. For instance, the cost of equipment was assessed as an important limiting factor for 3D printing and robotics, but a secondary issue for the adoption of sensors. On the other hand, the lack of skilled workforce particularly affects the adoption of Artificial Intelligence and Virtual and Augmented Reality, and limits the use of sensors only to a lesser extent.

Conclusions and lessons learnt

There is a consensus that digitalisation is both inevitable and pivotal for the competitiveness and sustainability of the European construction sector. Despite the lack of data relating to the level of digitalisation of the construction sector across the EU-27, a number of technologies are at a mature stage of development and have been adopted and mainstreamed by an increasing number of companies in the sector.

Policy initiatives can have a strong impact in fostering the adoption of digital technologies. Although this Report analysed digital technologies individually, it recognised the **high level of interconnection** among them. Hence, the maturity and adoption rate of an individual digital technology is partially linked to the development of other technologies, and this should be taken into consideration when developing public policies.

Digitalisation is both inevitable and pivotal for the competitiveness and sustainability of the of the European construction sector

As such, policymakers should adopt a holistic approach that takes into consideration the links and dependencies between different technologies, the national context and market structure for the sector. Stakeholders consulted for this study also confirmed the important role of EU-level measures pointing to the specific need for **three kinds of intervention: regulations, awareness raising campaigns, and financial support to construction companies**.

1 **An EU-level regulatory framework such as the one envisaged for the creation of the Single Market for Data was identified as of prime importance** for ensuring better data quality and data management, and for addressing challenges around intellectual property rights, cybersecurity, and data ownership.

2 **The EU can play a key role in raising awareness of digital technologies – especially to construction SMEs, which are often unaware and/or not convinced of their benefits.** SMEs need to be aware of financing opportunities, and the application process should also be tailored to their capacities and available resources.

3

The EU should increase financial support to companies, and especially SMEs, to invest in digital technologies. The new MFF places significant focus on the digital transformation. It includes Horizon Europe (budget of EUR 95.5 billion) and Digital Europe (EUR 7.5 billion) to support investments in digitalisation-related infrastructure, the deployment of digital technologies, and research and innovation.

EU policy should ideally focus on the planning, design, construction and operation and maintenance phases of the sector in order to effectively support its digitalisation. The other phases, i.e. renovation, demolition and recycling are less relevant entry points for most digital technologies and their digitalisation will come once the other construction phases are more digitalised. At the same time, in the long term it will be important for policy makers to ensure digitalisation of all phases in line with established circular construction policy objectives and their importance for renovation policy goals.

Developing and implementing a policy intervention in the construction sector is a highly complex exercise, that needs to be thought in a holistic manner – not only from a sectoral, but rather from a systemic perspective (i.e. including horizontal policies). In addition, if such an intervention ultimately aims to have an impact on the sector and its actors, it is key to identify where the interests of the private and public sector best align. An EU policy intervention could thus start by supporting the digitalisation of the first phases (i.e. the design and construction phases) of the construction value chains, where the private sector demonstrates most interest for digital technologies. Importantly, any policy interventions developed should be flexible to reflect the dynamics observed in the development and interest in different technologies, whose relevance can shift quickly. Last, it is important to note that any EU policy intervention should be evidence-based and backed by sufficient data (qualitative and quantitative) on the digitalisation of the construction sector. This report is a first move towards that direction, and future studies can build on it to delve into specific issues and topics.

The private sector demonstrates interest for EU policy intervention in the initial phases of the value chain

List of abbreviations

Abbreviation	Definition
AI	Artificial Intelligence
AR	Augmented Reality
BAS	Building Automation Systems
BIM	Building Information Modelling
BMC	BIM-based Model Checking
BPIE	Building Performance Institute Europe
CAD	Computer-Aided Design
CDW	Construction and Demolition Waste
CEN	European Committee for Standardisation
DESI	Digital Economy and Society Index
DIH(s)	Digital Innovation Hub(s)
EC	European Commission
EIB	European Investment Bank
EPC	Energy Performance Certificate
EU	European Union
FTE(s)	Full Time Equivalent(s)
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GHG	Greenhouse Gasses
GIS	Geographic Information System
ICT	Information and Communication Technology
IoT	Internet of Things
ISPU	Physical Planning Information System
IT	Information Technology
MS(s)	Member State(s)
PTNB	Digital Transition Plan in the Building
R&D	Research & Development
RDI	Research, Development and Innovation
RoI	Return of Investment
SMEs	Small and Medium-sized Enterprises
TEF(s)	Testing and Experimenting Facility(ies)
US	United States
VC	Venture Capital

1. Setting the scene

1.1 Background

The construction sector is a key pillar of the European Union (hereafter EU) economy, accounting for 18 million jobs and contributing to almost 9% of the GDP[1]. More than its economic weight, the sector has a major social, environmental and climate impact, including to the quality of life of EU citizens or CO_2 emissions and waste[2].

While the construction sector is a key driver of the EU economy, it faces several challenges relating to inter alia labour shortages, competitiveness, resource and energy efficiency and productivity. In fact, the construction sector's productivity grew at around a quarter of the rate of manufacturing (1.0% vs. 3.6% respectively) in the past two decades[3]. This issue is particularly important in times when the construction sector faces labour shortages and a profitability margin squeeze. The sector also generates 374 million tonnes of construction and demolition waste (CDW) in the EU, making it the largest producer of CDW in the EU in terms of mass[4].

Digital technologies and their integration in the construction sector are often viewed as a key element that can help tackle some of the aforementioned challenges. However, the construction sector is one of the least digitalised sectors in the economy[5,6]. With the exception of Building Information Modelling (BIM), few digital technologies have been widely adopted[7]. Yet, as recently highlighted in a European Commission (EC) report[8], the digitalisation of the construction sector goes beyond the sole use of BIM and includes data acquisition, automating processes and other digital information and analysis related technologies.

To support the digitalisation of the EU economy including the construction sector, policy makers at the EU and Member States (MS) levels have developed several policy initiatives. Some of these focus on the construction sector, such as the 'Strategy for the sustainable competitiveness of the construction sector and its enterprises' (2012)[9], or more recently the 'Renovation Wave' (2020)[10], while some others such as the new

1 European Commission (2020). Construction webpage as accessed on 02/11/2020. https://ec.europa.eu/growth/sectors/construction_en
2 For instance, buildings represent about 40% of energy consumption and 36% of CO2 emissions in the EU. https://ec.europa.eu/easme/en/news/sustainable-buildings-europe-s-climate-neutral-future
3 McKinsey (2016). Imagining construction's digital future. https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/imagining-constructions-digital-future
4 European Environment Agency (2020). Construction and demolition waste: challenges and opportunities in a circular economy. https://www.eea.europa.eu/themes/waste/waste-management/construction-and-demolition-waste-challenges
5 JRC (2019). Digital Transformation in Transport, Construction, Energy, Government and Public Administration. https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/digital-transformation-transport-construction-energy-government-and-public-administration
6 Committee for European Construction Equipment (2019). Construction: The least digitised sector in Europe. https://www.euractiv.com/section/digital/news/construction-the-least-digitised-sector-in-europe/
7 European Commission (2019). Supporting digitalisation of the construction sector and SMEs Including Building Information Modelling. https://ec.europa.eu/growth/content/report-supporting-digitalisation-construction-sector-and-smes_en
8 Ibid
9 European Commission (2012). Strategy for the sustainable competitiveness of the construction sector and its enterprises. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52012DC0433
10 European Commission (2020). A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1603122220757&uri=CELEX:52020DC0662

'Circular Economy Action Plan' (2020)[11] recognise construction as a key sector to achieve specific policy goals. Moving forward, the EU explicitly commits to digitalisation through the 'Digital Europe Programme' and 'Horizon Europe'[12]. Digitalisation is also part of some of the investment programmes of the EU, through 'InvestEU', which aims to finance projects related to research and innovation, digitalisation of industry, scaling up larger innovative companies, artificial intelligence and more[13]. These recent developments are expected to benefit the digitalisation of the whole EU economy, including the construction sector.

This Analytical Report looks at the issue of digitalisation in the construction sector across the EU-27, with a view to describe its state of play across the EU-27 and identify some of its main drivers and challenges. In doing so, the report provides information and evidence that will be relevant for wide range of stakeholders, including policy makers and other relevant actors, who wish to support the integration of digital technologies in the construction sector. Chapter 2 provides an overview of the state of play of digitalisation in the construction sector, from private and public sector perspectives, showing the extent to which digital technologies are adopted across EU MS. Chapter 3 dives into the main factors driving and hindering the uptake of digital technologies in the construction sector, by analysing some of the key policy trends and construction sector characteristics. Last, Chapter 4 highlights a set of lessons learnt and conclusions on the digitalisation of the construction sector and draws policy recommendations.

1.2 Methodology

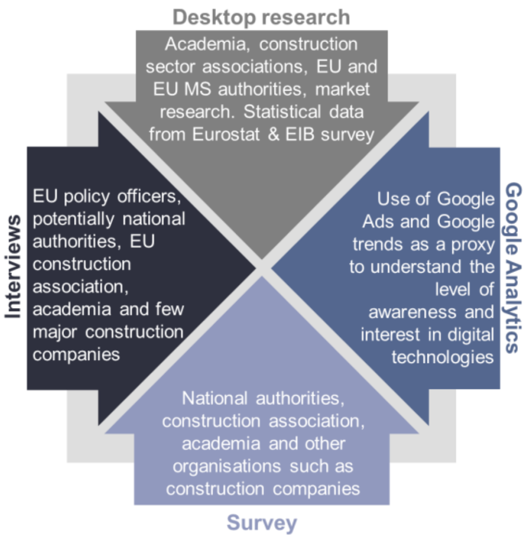
Data on the digitalisation of the construction sector is limited. In particular, data is i) scattered in several different places; ii) not always comparable between Member States as it is based on a different methodology or definition; iii) often circumscribed to the most mature technologies (BIM); and iv) often of qualitative nature. The approach and methodology of this report had to be adapted to cope with these issues.

[11] European Commission (2020). A new Circular Economy Action Plan. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN

[12] European Commission (2020). Europe investing in digital: the Digital Europe Programme. https://ec.europa.eu/digital-single-market/en/europe-investing-digital-digital-europe-programme

[13] European Commission (2018). InvestEU: what will it finance? https://ec.europa.eu/commission/sites/beta-political/files/budget-june2018-investeu-finance_en.pdf

Figure 1: A four-pillar methodology



Desktop review of publicly available EU and national data helped take stock of up-to-date information about developments for various digital technologies. In addition, a survey targeting policymakers, construction associations, companies and the academia was developed to provide a state of play of the digitalisation of the construction sector, looking at the extent to which digital technologies are adopted in each MS (see Annex 1). These sources were complemented by Google Ads and Google trends data, which were used as a proxy to assess the level of interest/awareness of digital technologies in the EU-27.

While the survey also provided data about the barriers and drivers of digitalisation in the construction sector, this analysis also relies on 15 semi-structured interviews with construction companies and associations (see more information in Annexes 3).

These were particularly useful in providing an understanding of which barriers / drivers are most important, and helped shape the analysis and recommendations presented in Chapter 4 – Lessons learnt and conclusions.

Box 1: Use of Google tools for data collection

Publicly available EU data on the awareness and interest of digital technologies is limited or not existing. To cope with this challenge, this report builds on alternative tools, namely Google trends and Google Ads. These tools provide information on the volume of searches, on Google / search partners, related to certain keywords defined by the user. Google Trends provides, for each keyword, a time-series or trend of how Google searches related with the keyword have changed over time. In addition, Google Trends also provides a comparison of search volume related to the keyword across countries. Last, the added-value of these tools is that they collect EU data following the same methodology, thus allowing for comparison between EU MS.

However, Google Trends does not provide the actual number of searches for a keyword. Rather it provides relative data in the form of an index relative to the highest search volume in a given search (relative to the highest level of searches in a given month, or the search volume in the country with the highest searches). This means that Google Trends can be used to examine trends in Google searches over time or across countries (e.g. whether searches for a certain keyword increased or decreased over time) – but not the number of searches (e.g. whether a certain keyword was searched for one thousand times or one million times).

In contrast, Google Ads provides data on the average number of searches per month over a given time period within set brackets (e.g. 10-100 searches, 100-1000, 1000-10000 searches). This allows a comparison of the actual search volume across MS and technologies.

Therefore, the analysis used data, collected from Google Ads, to provide a comparison of the search volume for various advanced technologies across MS (both in absolute terms and relative to population size). This was complemented by an analysis of the growth in interest in these technologies over time using data from Google Trends. The analysis is based on data retrieved using keywords in both English and the 24 European official languages[14].

The keywords referred to the technologies selected for the study. The option of combining the technology term with the key word "construction" was tested as a means of ensuring that the results capture

[14] See all the EU languages here: https://europa.eu/european-union/about-eu/eu-languages_en

information about the technology in the context of the construction sector. However, this approach captured only a very low level of search activity and was not conducive to carrying out cross-country comparison. Last, Google Trends data filters search volumes below a certain threshold. This resulted in a significant degree of missing data when using the construction key word restriction. While more specific key words could be combined with digital technology (such as architecture, infrastructure etc.), they were not considered as they would not apply equally to all technologies; additionally, as they are more specific and therefore produce a lower level of searches than e.g. construction, it leads to limited and/or missing data in several EU Member States. In turn this would limit the possibility for use and analysis of the data collected.

This report also focuses on a set of twelve digital technologies. These were selected based on i) the comprehensiveness of information available in the public domain; ii) their innovative character and potential benefits; and iii) the level of alignment with the European Commission priorities. Where possible, additional technologies were integrated in the report, as an illustration of what the next digitalisation steps could look like in the future in the construction sector.

1. Digital Building Logbooks;
2. Digital building permit system;
3. Digital Twins;
4. BIM;
5. 3D printing;
6. 3D Scanning;
7. Drones;
8. Sensors;
9. Internet of Things (IoT);
10. Robotics;
11. Virtual and augmented reality; and
12. Artificial intelligence

In total, 115 construction stakeholders from 24 countries filled up the survey. More than half came from the private sector, while 20% are public sector stakeholders, 9% construction associations and 7% academic institutes. Among the category "other", six stakeholders were identified as companies while the remaining were construction associations.

The 115 answers cover 24 EU MS, as illustrated in the figure below. The coverage is unequal, with Croatia being an outlier with their high number of responses. The figure below distinguishes between the 13 countries where public authorities provided answers (dark blue) and the remaining 14 countries where they did not (blue-gray).

Figure 2: Survey respondents by type

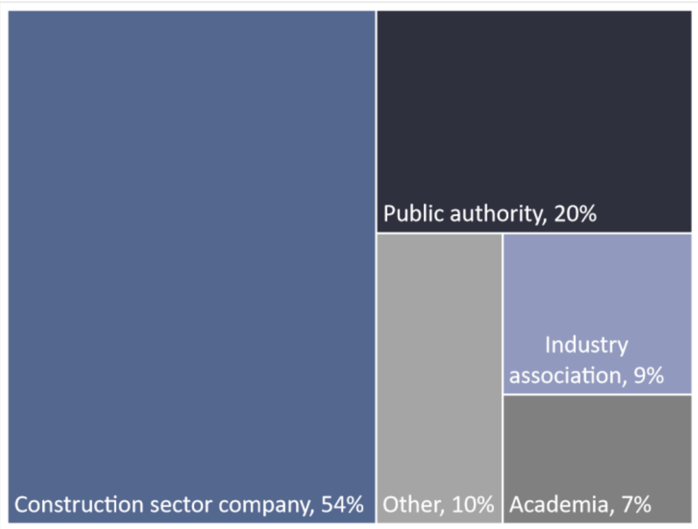
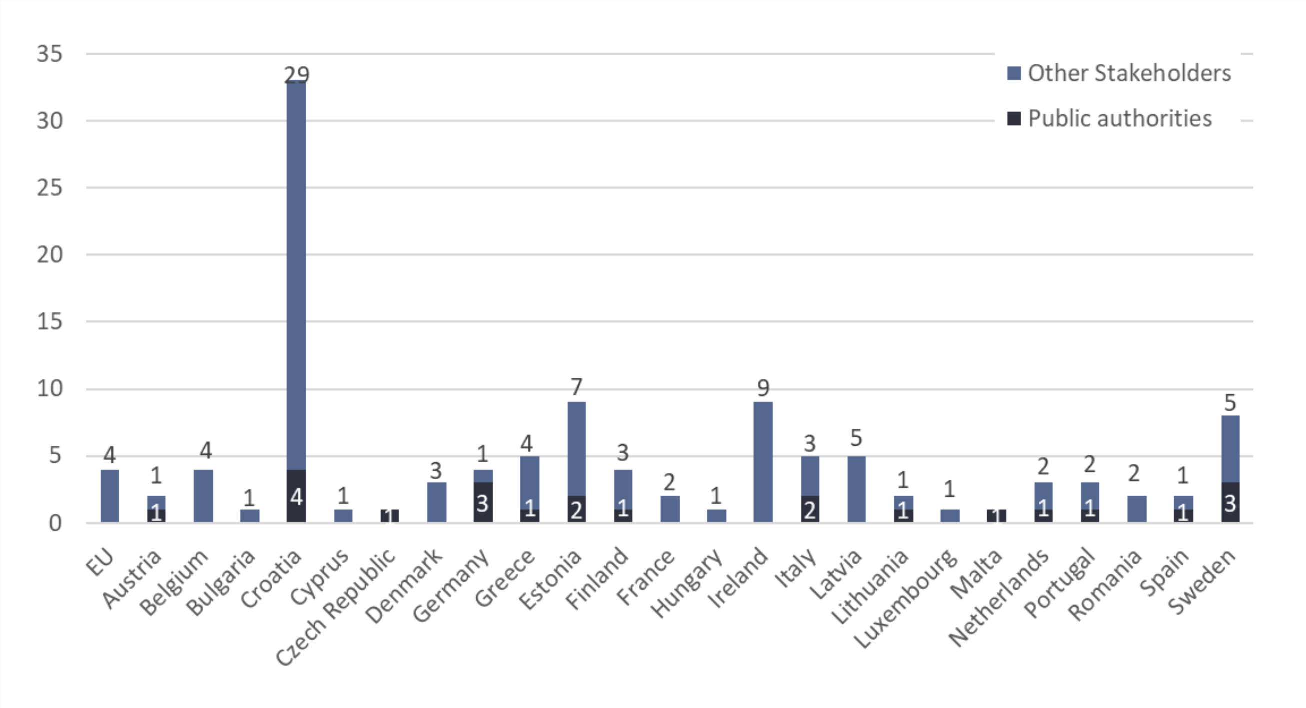


Figure 3: Overview of survey respondents by countries



The methodology adopted in this report has its own limitations. First, the survey was addressed to a sample of stakeholders (public authorities, academia and the construction sector) on the digitalisation of the construction sector, who are expected to have relevant knowledge about the topic discussed. However, the results are not statistically representative. This is important to take into account, should further studies on the digitalisation of the construction sector build on the approach and findings of this report. In addition, while various means of communication were used to increase the response rates of stakeholders, it is important to note that the number of respondents per country vary and no responses were received from the contacted stakeholders for three countries (Slovakia, Slovenia and Poland). Additional interviews were carried to gather further quantitative and qualitative data on the issue of digitalisation in the construction sector in these countries. The table below presents the stakeholders which were interviewed as part of this report.

Stakeholders interviewed	Type	Country
VITO	Private sector	Belgium
FIEC	Construction association	EU
Build Europe	Construction association	EU
DG CONNECT	Public authority	EU
JRC	Public authority	EU
Kirahub	Construction network	Finland
Eurac Research	Research institute	Italy
IDP Ingeniería y Arquitectura Iberia	Private sector	Spain
Besix	Private sector	Belgium
IVL Swedish Environmental Research Institute	Research institute	Sweden
University of Brescia	Research institute	Italy
FNV - Grootste vakbond van Nederland	Construction association	The Netherlands
VTT Technical Research Centre of Finland	Research institute	Finland
Bauindustrie Deutschland	Construction association	Germany
Buildings Performance Institute Europe	Research institute	Belgium

This report should be seen as a first stepping stone in terms of providing consolidated analysis for the state of play of digitalisation in the construction sector, on which future studies and reports can build on. Indeed, it is the first time when a report tries to gather EU-27 data on the digitalisation of the construction sector, by collecting secondary data from EU and national reports, studies, etc., and primary data through semi-structured interviews and survey. Future reports could enlarge the scope of stakeholders targeted by a survey, or deep dive into one of the technologies put forward in this report. Indeed, considering the rapid pace at which new technologies spread and evolve, it is of utmost importance to regularly monitor and update the information available, so that both policymakers and private stakeholders can take decisions based on the most recent evidence available.

1.3 Glossary

To ensure a common understanding of the analysis and takeaways presented in the report and ensure consistency with other documents from the European Commission, this report adopted the definitions of digital technologies in the construction sector based on Commission's report "Supporting digitalisation of the construction sector and SMEs. Including Building Information Modelling[15]":

- **Sensors**: sensor is any device that offers the possibility to collect data and monitor the performance of an aspect of a construction project (site, building, machine, etc.) during the whole building lifecycle, including operation and maintenance.
- **Internet of Things (IoT)** is the concept of connecting to the internet household appliances, devices, sensors, vehicles, etc. Thus, allowing for communication, remote control, exchange of data, etc. IoT is, currently, closely related to sensors as in most cases it requires some form of data provided by the sensors. However, as mentioned earlier, IoT could also be coupled with drones and 3D scanners which would lead to a better monitoring and inspection of construction projects.
- **3D scanning** is the process of creating a 3D model of a real-world object or construction by scanning it from all possible angles. This process can be used in the construction sector for creating 3D models of existing buildings and infrastructures for which there is no digital information.
- **Robotics** in the construction sector consists of the use of devices with robotic arms which operate repetitive processes such as laying floor tiles or bricks, lifting heavy objects and placing them in exact coordinates.
- **3D printing**, or additive manufacturing, is the process of creating an object by solidifying a material (e.g. plastic, metal, wood or concrete) under the control of a computer using a Computer-Aided Design (CAD) or BIM file to guide the 3D printer nozzle. In the construction sector, 3D printing can be used to create building components or to print entire buildings. It has been used for buildings, bridges, printed moulds or architectural models.
- **Drones** are unmanned aerial vehicles equipped with high-resolution cameras and other scanning equipment. Drones can scan large areas or different directions/angles of an object simultaneously, thus allowing for reality-capture solutions and real-time comparison between planned and implemented solutions.
- **BIM, acronym for Building Information Modelling** is a digital form of construction and asset operations. It brings together technology, process improvements and digital information to radically improve client and project outcomes and asset operations. BIM is a strategic enabler for improving decision making for both buildings and public infrastructure assets across the whole lifecycle. It

[15] European Commission (2019). Supporting digitalisation of the construction sector and SMEs, Including Building Information Modelling.

applies to new build projects; and crucially, BIM supports the renovation, refurbishment and maintenance of the built environment which have the largest share of the sector[16].

- **Virtual and augmented reality**: Virtual reality (VR) involves a detailed virtual model of the project and places the user directly inside the virtual environment, so that it is possible to experience the building before or during its realisation[17]. Augmented reality (AR) is a digital view of a real and physical environment / object whose elements are augmented (or supplemented) by computer-generated sensory input[18].
- **Artificial intelligence** (AI) is a disruptive technology consisting of a machine that through Artificial Neural Networks mimics human cognitive functions, like problem-solving, pattern recognition, and learning. It has recently acquired ground-breaking capabilities thanks to important progresses made in computational power, and whose impact can stretch through the whole lifecycle of a building[19].
- **Digital Twin** is the real-time digital representation of the physical building or infrastructure. Usually, data is gathered by on-site sensors that continuously monitor changes in the building and in the environment and update the BIM model with the most recent data and measurement[20].
- **Digital construction platforms** are virtual or physical platforms gathering private and public stakeholders, aiming to support the integration of digital technologies in the construction sector. These can also take the shape of “associations”. National digital platform related to construction play a role in helping implementing construction policies by e.g. coordinating the digitalisation of public and private stakeholder initiatives, providing space for dialogue[21].

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16 EUBIM Task group (2017). Handbook for the introduction of BIM by the European Public Sector. http://www.eubim.eu/downloads/EU_BIM_Task_Group_Handbook_FINAL.PDF

17 BIM360 Resources (2018). 3 Ways Virtual Reality in Construction is shaping the industry. https://bim360resources.autodesk.com/connect-construct/3-ways-virtual-reality-in-construction-is-shaping-the-industry

18 Redshift (2018). What is augmented reality, and how can it help architects and contractors? https://redshift.autodesk.com/what-is-augmented-reality/

19 JRC (2019). Digital Transformation in Transport, Construction, Energy, Government and Public Administration.

20 IntellectSoft (2018), Advanced imaging Algorithms for Digital Twin Reconstruction. https://www.intellectsoft.net/blog/advanced-imaging-algorithms-for-digital-twin-reconstruction/

21 This definition is a working definition used in this report as the research carried out did not identify a widely accepted definition for this term.

2. State of play of digitalisation in the construction sector

2.1 Introduction

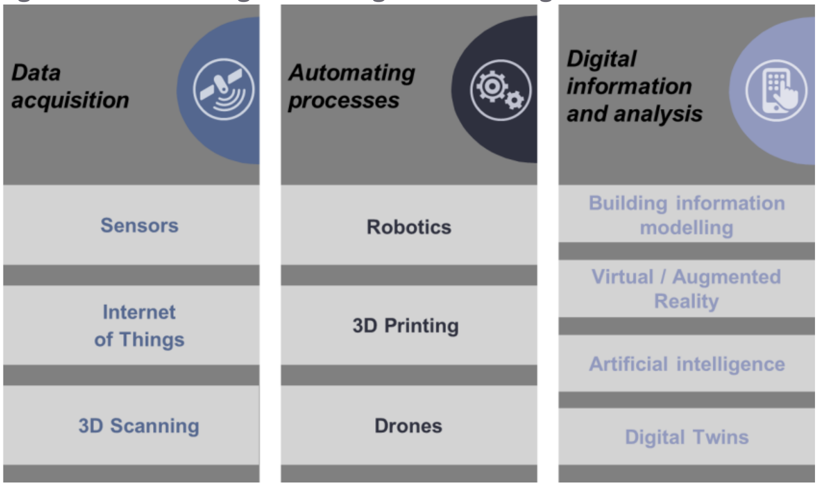
Digitalisation in the construction sector can bring significant opportunities for the whole value chain not only by improving existing practices, but also by integrating disruptive technologies and tools that can lead to new processes, business models, materials, and solutions. In sum, digital technologies can help the sector build better, and tackle several issues, including labour shortages, labour productivity, waste and greenhouse gas emissions, health and social challenges.

This chapter aims to provide an overview of where the construction is, when it comes to digitalisation. It does so by analysing the issue of digitalisation from a private sector perspective. This chapter will hence look at the level of integration by the construction sector of digital technologies grouped in three categories: i) data acquisition technologies (e.g. sensors); ii) automation processes (e.g. robotics); and iii) digital information and analysis (e.g. BIM).

2.2 Digitalisation of the EU construction sector

This first section analyses the main digital technologies adopted in the construction sector based on their level of awareness, adoption rates, market development, and the benefits they can bring. The technologies are organised in three categories: data acquisition, automating processes, and digital information and analysis (as illustrated in Figure 4).

Figure 4: Three categories of digital technologies in construction[22]



Source: Adapted from JRC (2019).

Data acquisition refers to the unprecedent availability of massive amounts of data from sensors, scanners and connected devices (IoT) concerning all aspects of the construction, from geo-localisation to humidity levels, from energy usages to air quality, from video recordings to seismic measurements. The availability of this data will allow for a growing range of analytical services to improve productivity in the construction

[22] JRC (2019). Digital Transformation in Transport, Construction, Energy, Government and Public Administration. https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/digital-transformation-transport-construction-energy-government-and-public-administration

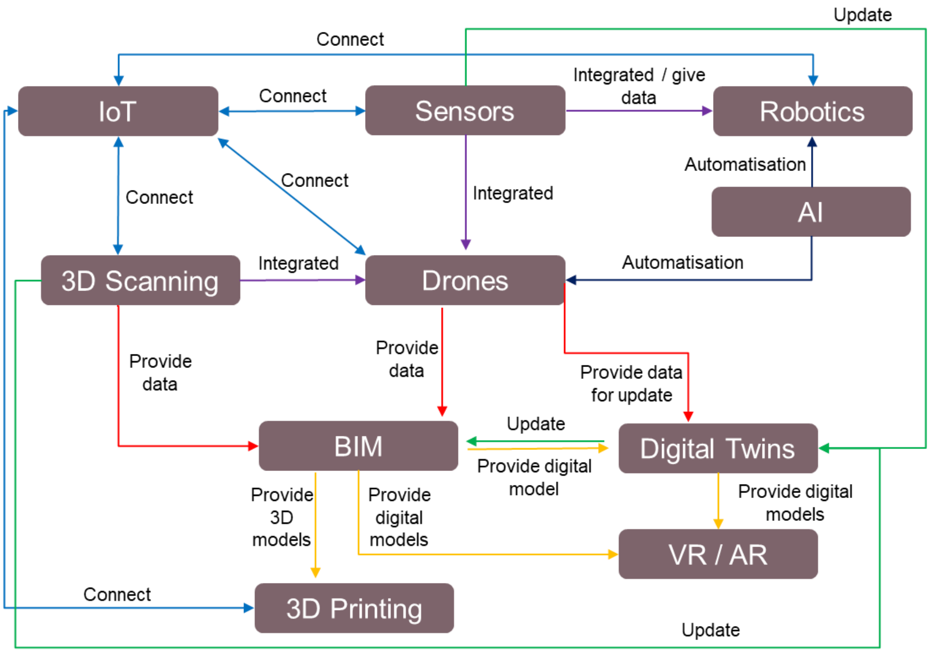
process in all its phases (e.g. design and engineering, construction, operation and maintenance etc.) and its sub-sectors (e.g. real estate, manufacturing, architecture and engineering).

Automation processes through the adoption of robots, 3D printing, drones and other machineries play a very important role in the development and modernisation of the sector. By automating certain activities, not only the final quality of the project increases, but workers are also less exposed to risks and new materials and techniques can be deployed. This category of digital technologies is hence most relevant for the construction phase which is often overlooked when it comes to the digitalisation of the sector[23].

Considering the two categories just mentioned, digital information and analysis is, therefore, crucial for connecting all innovative technologies in this sector and processing the available data, thus leading to significant improvements and transformations in the way the work is done. In fact, the added value of having real-time information, precise measurements, and historical stock-taking databases will be increasingly important and essential for the sustainability and competitiveness of the sector[24].

The technologies presented are, in some cases, heavily interconnected. To give an example, the report analyses sensors, drones, and robotics as three separate technologies; however, drones can be equipped with various sensors and robotic parts. At the same time, 3D scanning, BIM, Augmented reality and Digital Twins are also deeply interconnected, as they refer to similar technologies being used in different ways or to different stages of the same technology (e.g. augmented reality in the construction sector can be seen as the combination of BIM projects with visual sensors; a Digital Twin is a BIM project regularly updated by using data from several sensors, scanners, etc.). Figure 5 below provides a high-level overview of some of the possible interactions between different digital technologies mentioned in this report. This Figure is not meant to capture all possible interactions and implementations, but rather provides a concrete illustration of their interconnectedness as aforementioned.

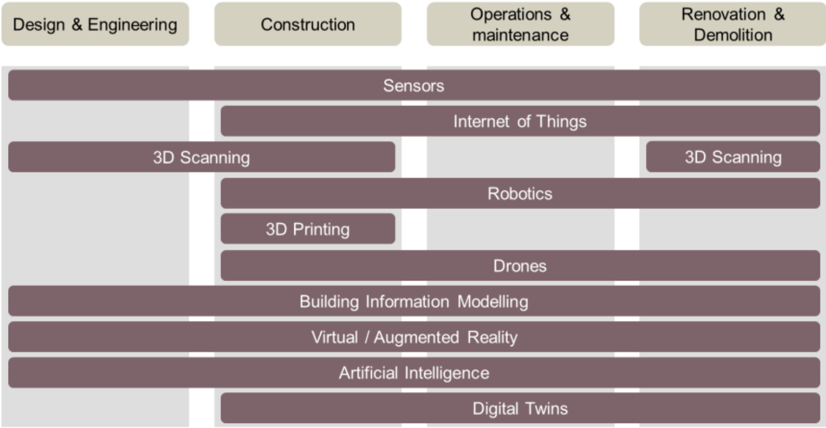
Figure 5: Overview of the interactions among digital technologies in the construction sector



23 ECSO (2019). BIM in the EU construction sector. https://ec.europa.eu/docsroom/documents/34518/attachments/1/translations/en/renditions/native

24 ESub (2020). How Big Data and Analytics are transforming the Construction Industry. https://esub.com/blog/how-big-data-analytics-transforming-construction-industry/

Figure 6: The use of digital technologies in the Construction sector[25]



Source: Adapted from JRC (2019).

Digital technologies can be applied not only throughout all phases of the construction process, but also at any point of the building's lifecycle (see Figure 6). However, these technologies tend to be used mostly in specific cases, such as in historical heritage sites to appreciate the assets and in newly constructed buildings, as it is easier and more cost-effective to integrate them from the beginning and structure the project based on their use, rather than undertake additional investments to implement them in already-existing buildings.

Nevertheless, as recognised by the European Commission in the Renovation Wave Communication[26], the renovation of existing buildings plays a very important role in tackling climate change, as the majority of existing buildings are not energy-efficient[27]. In fact, 85% of the European building stock was built before 2001, and will likely still be in place in 2050[28]. This represents a major challenge, as failing to embrace the green and digital transformation of the construction sector (including in renovation activities) will hamper the EU's objectives in terms of competitiveness and sustainability.

2.2.1 Data acquisition

2.2.1.1 Sensors

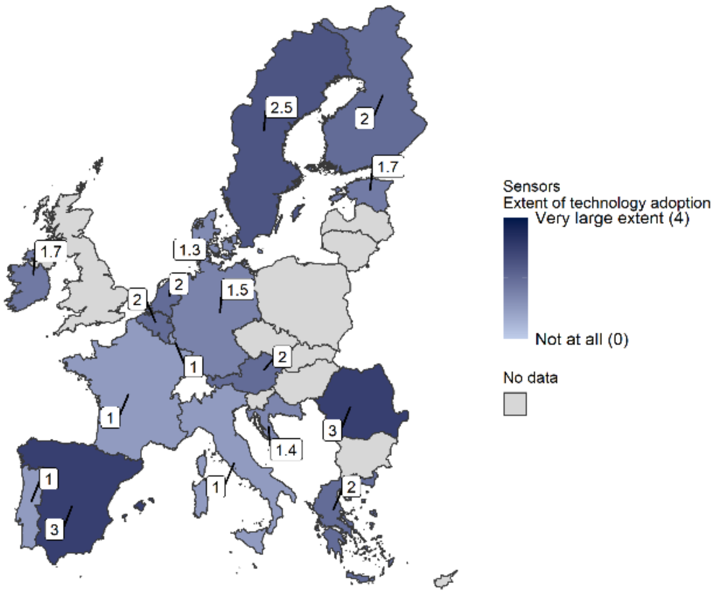
Sensors are electronic devices that offer the possibility to collect data and monitor the performance of individual types of information (e.g. electricity consumption, indoor air temperature, CO_2 concentration)[29] **during the building's entire lifecycle**, namely in the architectural design, engineering, construction, operation and maintenance, renovation and demolition phases[30].

Over the last several years, the use and adoption of sensors have increased significantly in the construction sector. According to the survey and the interviews carried out for the purposes of this report, at present, sensors are being used across all EU MS. However, responses to the survey, although incomplete, highlighted differences in terms of their level of the adoption (see Figure 7). Spain, Romania, Sweden, the Netherlands and Belgium appear to be the countries with the strongest adoption.

This positive trend for the growth in adoption of sensors is also confirmed by the interest companies have shown over the last five years, which can be assessed by analysing online search behaviour. Although not specific to the construction sector, the analysis of Google trends data shown an EU average increase in online interest[31] in sensors of around 15.5% between 2015 and 2020 (see Figures 8 and Figure 9 below).

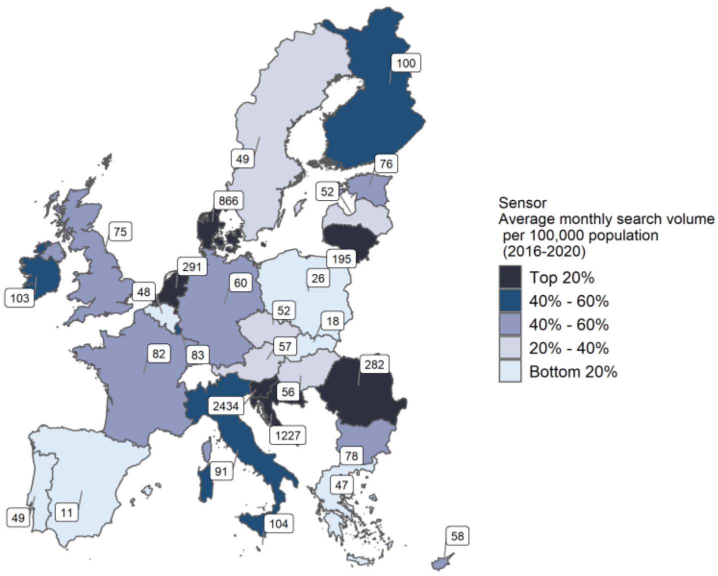
25 JRC (2019). Digital Transformation in Transport, Construction, Energy, Government and Public Administration. https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/digital-transformation-transport-construction-energy-government-and-public-administration
26 European Commission (2020). Renovation Wave Communication. https:/eur-lex.europa.eu/legal-content/EN/TXT/?qid=1603122220757&uri=CELEX:52020DC0662
27 JRC (2019). Digital Transformation in Transport, Construction, Energy, Government and Public Administration.
28 European Commission (2020). A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives. COM (2020) 662 final.
29 ECSO (2019). Supporting the digitalisation of the Construction sector and SMEs.
30 JRC (2019). Digital Transformation in Transport, Construction, Energy, Government and Public Administration.
31 Assessed based on the number of online researches on Google per Member State.

Figure 7: Extent of sensors adoption in EU MS[32]



Source: ECSO survey, 2020

Figure 8: Average monthly sensors online search volume (2016-2020)[33]



Source: Google Ads, 2020

Sensors are amongst the data acquisition technologies with the highest level of market readiness[34], and represent the central point for the future of the construction sector, both in the EU and in the world. As the sector gradually moves towards data-driven models, sensors will become increasingly important as they represent the main source of real-time data, both on the construction site and once the building has been completed. However, as four of the stakeholders who were interviewed highlighted, there is still a gap between new buildings, which generally tend to have a greater adoption of sensors, and older ones, which are the majority of existing buildings and where the investment to upgrade them with sensors sometimes not undertaken due to the costs required[35].

However, sensors have been developing rapidly over the last several years and, as they mature, they are also becoming increasingly accessible – also for smaller companies and for the purpose of smaller tasks (e.g. wearables to monitor workers' safety) – and practical (e.g. smaller dimensions, higher energy efficiency, etc.)[36]. In addition, given the wide range of models and functions, sensors can be used on a variety of tasks in the construction value chain. For instance, sensors can be used by architects and project managers to **monitor the environment of construction sites**[37] (e.g. humidity level, presence of gasses, etc.) and detect local variations in material strength or work integrity, as well as to **keep monitoring the buildings once they have been completed** (e.g. long-term health of concrete).

[32] The map is based on survey results. 46 participants responded to this question. Countries coloured in grey are those for which no data was available. ECSO survey result is not statistically representative and should be interpreted accordingly.

[33] The map is based on the analysis of Google research data. Countries coloured in grey are those for which no data was available.

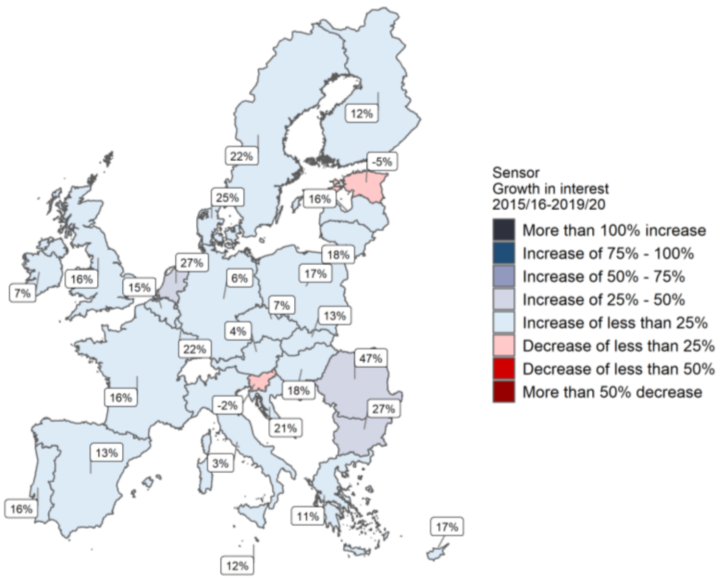
[34] Information retrieved from interviews.

[35] Information retrieved from interviews.

[36] JRC (2019). Digital Transformation in Transport, Construction, Energy, Government and Public Administration.

[37] Constructionblog (2020). Sensors in Construction. https://constructionblog.autodesk.com/sensors-in-construction/

Figure 9: Sensors' growth in interest (2015-2020)[38]



Source: Google Trends, 2020

Sensors can wirelessly deliver **real-time updates on a project status**, the location of vehicles, deliveries and assets, or the condition of various features as they are built[39], thus providing a significant amount of precious and updated data to construction companies and other stakeholders.

On the contrary to some traditional measurement practices, sensors can benefit the construction sector during the building's entire lifecycle[40]. During the design phase, sensors are often integrated in drones to **survey the future construction site** and assess its conditions and characteristics, as well as to take photos and precise measurements[41]. This allows architects and other actors involved in the design phase to develop their design while having access to very precise data on the building environment.

During the construction phase, sensors have a three-fold benefit: prevention and safety, optimisation, and efficient management[42]. In fact, a sensor embedded in a machine allows machine operators and site managers to **promptly assess when the machine needs maintenance**[43], thus not only reducing overall reparation costs for companies, but also decreasing the risks for the personnel using the machine. Throughout the entirety of the maintenance of the building, the use of sensors also facilitates the **transition from planned maintenance towards predictive maintenance**, leading to cost and disturbance reductions for the final users[44], as problems are proactively addressed based on real-time machine data collection, thus identifying issues at nascent stages before they can affect the project.

The same logic can be applied to **sensors embedded in personal protective equipment** used during construction, which can significantly improve safety in construction sites and protect workers' health[45].

In the context of the operation of buildings, sensors can be used to monitor offices' and households' internal and external environments to maintain optimal and safe working and living conditions, while also optimising energy use. For instance, sensors can be used by facility managers and owners to regulate the heating / air conditioning, monitor air quality, turn on / off the lights, detect excessive noise levels, and close the windows if rain or strong winds are sensed[46,47]. At the same time, motion and video sensors can be

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38 The map is based on the analysis of Google research data. Countries coloured in grey are those for which no data was available.

39 Euroscientist (2020). Smart sensors are a game changer for the construction industry. https://www.euroscientist.com/smart-sensors-are-a-game-changer-for-the-construction-industry/

40 Giatecscientific (2018). The Benefits of using sensors in the Construction Industry. https://www.giatecscientific.com/education/the-benefits-of-using-sensors-in-the-construction-industry/

41 BDC Network. Drones for AEC: How every stage of a building project can benefit from drone technology. https://www.bdcnetwork.com/blog/drones-aec-how-every-stage-building-project-can-benefit-drone-technology

42 Giatecscientific (2018). The Benefits of using sensors in the Construction Industry.

43 Euroscientist (2020). Smart sensors are a game changer. https://www.euroscientist.com/smart-sensors-are-a-game-changer-for-the-construction-industry/

44 JRC (2019). Digital Transformation in Transport, Construction, Energy, Government and Public Administration.

45 Ibidem.

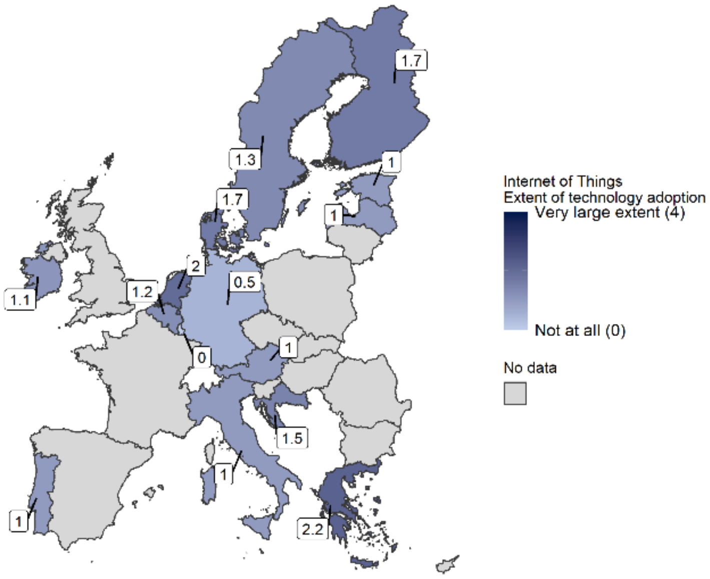
46 LEDs Magazine (2020). Smart building sensors provide the foundation for the decade of data. https://www.ledsmagazine.com/smart-lighting-iot/article/14180024/smart-building-sensors-provide-the-foundation-for-the-decade-of-data-magazine

integrated in the building's security system, and eventually connected to the cloud, to improve the safety of the area. Sensors are also being increasingly integrated onto **heritage sites or infrastructure**, such as bridges, and used to monitor their conditions, in order to undertake timely interventions as soon as a potential issue is detected or foreseen.

Indeed, sensors can not only collect data, but they also direct this data to computers and cloud networks for analysis[48], for example through IoT systems, and feed directly into Digital Twins, BIMs, etc., or used for other analytical (e.g. benchmarking of energy performance) and functional (e.g. regulating the heating) purposes. This allows both construction companies and final users to gather relevant information and assess ways to optimise, for example, fuel spending and energy usage, to **reduce costs** and make the most out of their machines and equipment, thus **maximising Return on Investment** (RoI). In this context, sensors can contribute to create a more efficient supply chain, and hence improve the timelines of projects and foster better communication with clients. Finally, sensors can reduce the risk and cost of repairs and breakdowns through the predictive maintenance mentioned above, which can bring up to 20% of cost reduction in the total lifecycle of a project[49]. This reduction is achieved by **real-time data collection**, which allows companies to assess the status and productivity of their machineries and equipment, thus promptly understanding when the machine needs repair. Furthermore, tests are being carried out on the use of sensors to **detect and automatically sort construction waste**, through, for example, electromagnetic and infrared sensors and colour cameras[50].

2.2.1.2 Internet of things

Figure 10: Extent of IoT adoption in EU MS[51]



Source: ECSO survey, 2020

Internet of Things (IoT) is the concept of connecting to the internet household appliances, devices, sensors, vehicles, etc. thus allowing for communication, remote control, exchange of data, etc. For this reason, IoT is closely related to sensors as, in most cases, they provide IoT with the required data input, alongside drones and 3D scanners[52]. At the same time, IoT technology is deeply intertwined with the concept of **cloud computing**, i.e. external servers equipped with storage capacity and specific data processing software[53]. By leveraging on cloud computing, IoT can gather data from different physical devices (e.g. sensors, working machines, etc.) and outsources the analysis and / or storage of

47 Pressac (2020). Types of Smart Building Sensor and how they work. https://www.pressac.com/insights/types-of-smart-building-sensor-and-how-they-work/

48 Giatecscientific (2018). The benefits of using sensors. https://www.giatecscientific.com/education/the-benefits-of-using-sensors-in-the-construction-industry/

49 Ibidem.

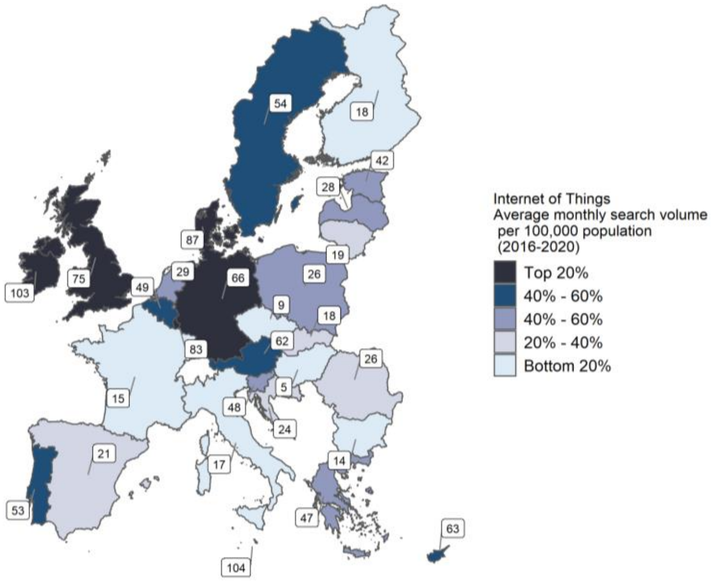
50 InnoçSD, Advanced Sorting Techniques for Construction and Demolition Waste. https://www.inno4sd.net/advanced-sorting-techniques-for-construction-and-demolition-waste-278

51 The map is based on survey results. 53 participants responded to this question. Countries coloured in grey are those for which no data was available. ECSO survey results are not statistically representative and should be interpreted accordingly.

52 ECSO (2019). Integrating digital innovations in the construction sector.

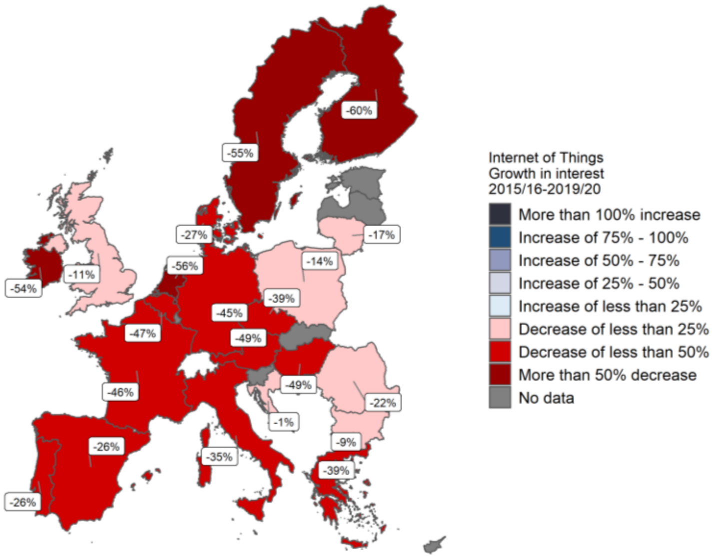
53 Design in Buildings. Cloud computing and BIM for the construction industry. https://www.designingbuildings.co.uk/wiki/Cloud_computing_and_BIM_for_the_construction_industry

Figure 11: Average monthly IoT search volume (2016-2020)[54]



Source: Google Ads, 2020

Figure 12: IoT's growth in interest (2015-2020)[55]



Source: Google Trends, 2020

such data to the cloud[56], hence without the need for such software to be installed directly into the devices and with the possibility to access to such data from multiple devices.

IoT has a low adoption rate in the EU when compared to, for example, the USA, with only around one fourth (26%)[57] of European companies starting to use this technology, against a 40% average in the USA. The adoption rates are similar between start-ups and scale-ups, with the latter having only a marginally higher adoption level[58]. This low adoption rate can be explained by the fact that i) IoT is not yet considered a fully mature technology and its implementation is often limited to pilot projects[59,60]; and ii) it partly depends on the development of other digital technologies in the sector, such as drones, sensors, and scanners, which allow data and devices to be connected[61]. This is also reflected in the responses to the survey carried out in the context of this Analytical Report. As Figure 10 shows, respondents from several EU MS did not provide any answer. This can be read as a low awareness of the technology due to its low market maturity, rather than simply low adoption rates.

The low market maturity of IoT is also reflected in the limited interest it generates among companies, with the exception of German, Danish, and Irish companies (see Figure 11). According to stakeholders who were interviewed, this is due to the fact that some companies do not concretely see how to turn IoT potential

54 The map is based on the analysis of Google research data. Countries coloured in grey are those for which no data was available.
55 The map is based on the analysis of Google research data. Countries coloured in grey are those for which no data was available.
56 Ibidem.
57 European Investment Bank (2019). Investment Survey 2019
58 European Investment Bank (2019). EIBIS Report on Digitalisation. https://www.eib.org/attachments/efs/eibis_2019_report_on_digitalisation_en.pdf
59 Information retrieved from interviews.
60 Information based on the survey. ECSO survey results are not statistically representative and should be interpreted accordingly.
61 Information retrieved from interviews.

into actual benefits yet, and thus, they do not prioritise its development and adoption[62]. In 2020, the general online interest in IoT actually decreased by 36.3% compared to 2015 levels[63], as shown in Figure 12.

As mentioned, IoT is an emerging technology in the construction sector and its application is still primarily in the R&D phase (i.e. it is not industrialised yet). In turn, its limited use hinders its visibility and attractiveness for the private sector. Nonetheless, it is reasonable to say that its implementation is being tested mainly in the construction, management, and demolition phases.

During the construction phase, IoT can be used by project managers and site supervisors to monitor workers' safety by using a system of connected sensors to ensure that they are not exposed to hazardous substances or to situations of physical danger. Furthermore, by connecting building machinery to the cloud, IoT allows to manage the fleet and, more generally, the construction process remotely[64], which can facilitate construction in areas that are not accessible to workers, that are polluted, or dangerous to be in[65]. Preliminary studies have linked the use of IoT in construction projects with an estimated average **cost saving** around 22 – 29% of the total project costs[66].

In the management of buildings, facility managers and building owners can use IoT to connect different devices, such as sensors for room temperature, electrical power measuring, and actuators for heating, ventilation, and air conditioning (HVAC Systems) to provide structural monitoring and energy savings[67]. In more complex buildings, these controls can be automated, e.g. via programmable logic controllers to execute building automation[68]. IoT devices can be integrated in any device that consumes energy, such as lamps, switches, televisions, or power outlets, and can be used for communicating with utility supply companies to effectively balance energy usage and power generation. Optimising building controls can increase comfort in the building and save energy, either automatically or by providing feedback on building occupant behaviour. Indeed, some studies have estimated that IoT can bring an up to 35% of energy consumption reduction[69] obtained by using coordinated digital building systems. In this context, IoT plays an important role in saving energy particularly when energy sources and outputs in buildings become more complex, for example when a building has a significant energy consumption due to electric vehicles, electricity generation capacity through photovoltaic panels on the roof, heating capacity through a heat pump, or storage capacity through a hot water tank or batteries[70].

Finally, IoT can support construction and demolition waste management activities[71]. More specifically, IoT allows for the deployment of sensor-based tools for monitoring on-site trash levels, determining how waste loads vary across the year and, thus, optimising the operating mode to prevent waste pileups. At the same time, it allows for the calculation of the most efficient waste collection routes in order to reduce recycling and disposal costs[72]. Additionally, the use of interconnected sensors can offer business owners the possibility

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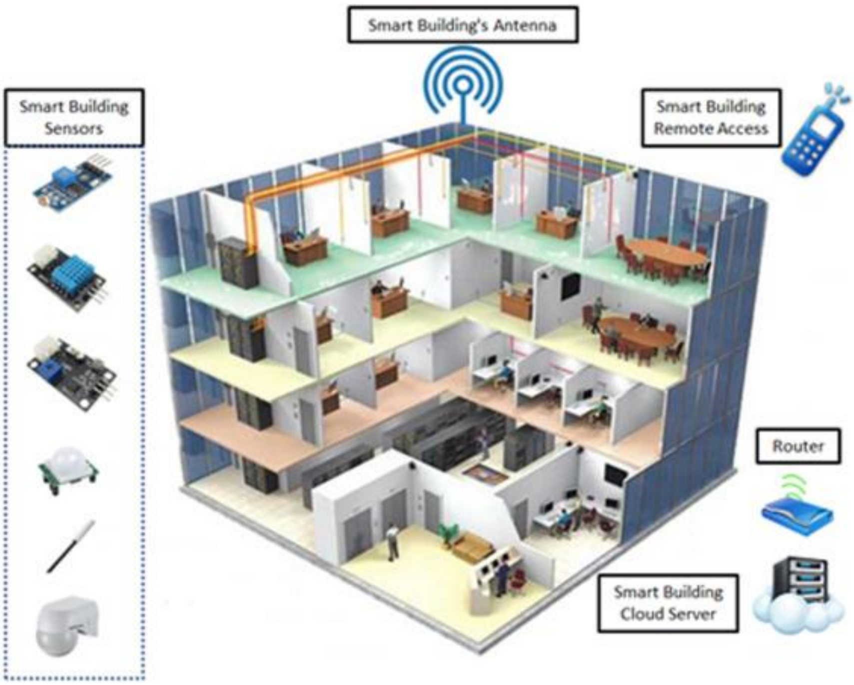
62 Information retrieved from interviews.
63 Assessed based on the number of online researches on Google per Member State.
64 Allerin (2019). Transforming the Construction industry with IoT. https://www.allerin.com/blog/transforming-the-construction-industry-with-iot
65 Digiteum (2020). How IoT can improve the construction industry. https://www.digiteum.com/iot-construction-industry
66 Ghosh, Edwards, and Hosseini, M.R. (2020). "Patterns and trends in Internet of Things (IoT) research: future applications in the construction industry", Engineering, Construction and Architectural Management.
67 JRC (2019). Digital Transformation in Transport, Construction, Energy, Government and Public Administration.
68 Buildup.eu. OVERVIEW | Next generation buildings: IoT and smart energy efficiency. https://www.buildup.eu/en/news/overview-next-generation-buildings-iot-and-smart-energy-efficiency
69 Window Master. Smart IoT Building Solutions reduce global energy demand. https://www.windowmaster.com/expertise/trends-and-insights/smart-iot-building-solutions-reduce-global-energy-demand/
70 Buildup.eu. OVERVIEW | Next generation buildings: IoT and smart energy efficiency.
71 You, Wu, Zheng, Feng (2020). "An Informatization Scheme for Construction and Demolition Waste Supervision and Management in China".
72 Digiteum. How IoT can improve the construction industry. https://www.digiteum.com/iot-construction-industry

to have real-time waste management data, used for reporting and improvement practices, as well as for the development of automated waste recycling protocols[73].

Figure 13: Efficient IoT-based sensors BIG Data collection–processing and analysis in smart buildings[74]



Source: Plageras, et al. (2018)

2.2.1.3 3D Scanning

3D scanning is the process of creating a 3D model of a real-world object or building by scanning it from all possible angles. A 3D scanner emits millions of laser points. By calculating how long the light takes to return and by measuring the coordinates of the laser points and how the angles change, the scanner accurately calculates the shape, dimension and the location of the object(s) scanned[75]. Depending on the 3D scanner used (i.e. if it is equipped with a GPS device), the data points gathered can also include topographic data of the scanned buildings[76]. This process can be used in the construction sector to create 3D models of existing buildings and infrastructures for which there is no digital information. The 3D data captured by the scanners is then incorporated in BIM models or Digital Twins for further elaboration and use with the information already available.

Although there is no precise data on 3D scanners adoption across the EU, the 3D scanner market in Europe is expected to grow by more than 11% yearly from 2018 to 2023[77], as companies are increasingly adopting 3D scanners for on-site construction activities[78]. The rising adoption rates are largely due to scanners' costs gradually lowering thanks to economies of scale taking place. Figure 14 shows the level of 3D scanner

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73 Sartipi, F. (2020). Influence of 5G and IoT in construction and demolition waste recycling - conceptual smart city design.

74 Plageras, A.P.; Psannis, K. E.; Stergiou, C.; Wang, H.; Gupta, B.B. (2018). Efficient IoT-based sensor BIG Data collection–processing and analysis in smart buildings, Future Generation Computer Systems 82: 349-357.

75 ScanTech Surveys. The Benefits of 3D Laser Scanning for Construction. https://www.scantechsurveys.co.uk/the-benefits-of-3d-laser-scanning-for-construction/

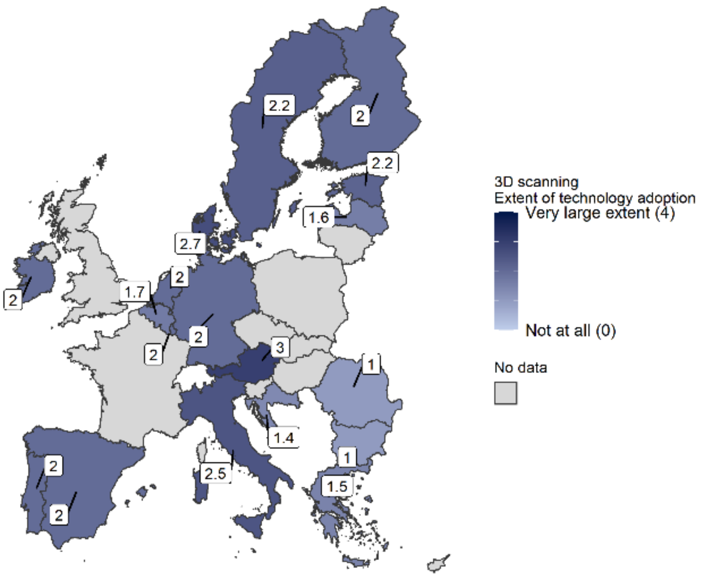
76 Li, L.; Xiangyan, C.; He, Q.; Sun, J.; Jia, B.; Dong, X. (2019). A new 3D laser-scanning and GPS combined measurement system. Comptes Rendus Geoscience 351(7): 508-516.

77 Research and Markets, Europe 3D Scanner Market - Forecasts from 2018 to 2023. https://www.researchandmarkets.com/research/szv4p9/european_3d?w=5

78 Information based on the survey. ECSO survey results are not statistically representative and should be interpreted accordingly.

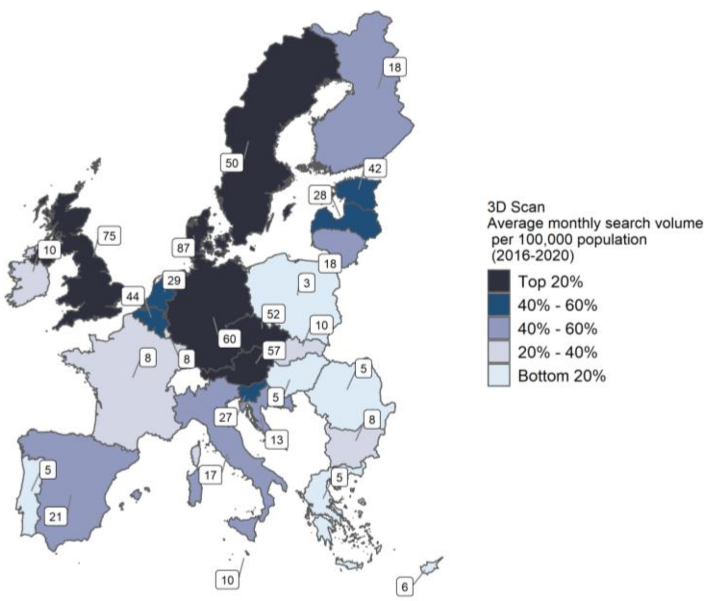
adoption across the EU, based on the survey carried out for this analysis. Despite the missing data from several MS, the adoption appears to be sound across most of the EU MS. This is also reflected in the average number of monthly online search on 3D scanning.

Figure 14: Extent of 3D scanner adoption in EU MS[79]



Source: ECSO survey, 2020

Figure 15: Average monthly 3D Scan search volume (2016-2020)[81]



Source: Google Ads, 2020

Although the number of searches is relatively low when compared to other technologies (even the country with the highest search volume, Germany, has less than 50,000 online interactions per month, on average), there is a moderate increase in the general interest in the technology, evenly spread across all EU MS (Austria, Slovakia, Denmark and Romania registered the highest growth online (see Figures 15 and 16), in line with its growing diffusion in construction sites[80].

The growing utilisation of 3D scanners in the construction sector is due to recognised applications and the improvements they provide. Before, during, and after the construction phase, 3D scanning can be used for surveying and analysing a wide range of construction types and locations, with greater precision than other tools. The acquisition of precise point clouds of existing structures and their conversion into 3D models is crucial in the digitalisation of the construction sector.

For the moment, although used in most EU MS, results from the survey showed that **3D scanning still has a moderate** market adoption[82], being used mainly by start-ups and public authorities in cultural heritage preservation[83] (see Figure 17, for example) and in pilot projects.

The main benefits of 3D scanning in the construction sector are generally two-fold[84]. First, scanning allows a rapid and precise measurement and collection of millions of data points in a very time-

[79] The map is based on survey results. 56 participants responded to this question. Countries coloured in grey are those for which no data was available. ECSO survey results are not statistically representative and should be interpreted accordingly.

[80] Information retrieved from interviews.

[81] The map is based on the analysis of Google research data. Countries coloured in grey are those for which no data was available.

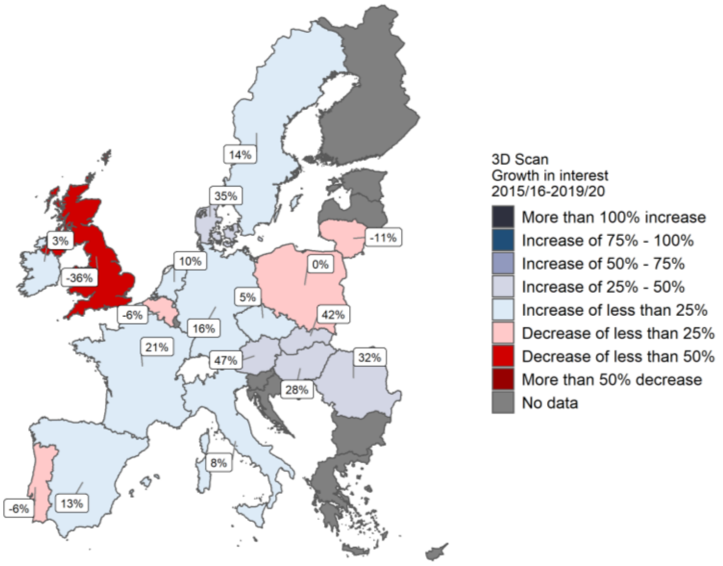
[82] Information based on the survey. ECSO survey results are not statistically representative and should be interpreted accordingly.

[83] Historic England. 3D Laser Scanning for Heritage.

[84] UK Construction Media. 3 Key benefits.

efficient and accurate way. Secondly, since the data gathered is much more accurate, this removes the necessity of guesswork, second measurements and approximations, which all increase the final cost of the project and increase the possibility of errors. In fact, it is estimated that the adoption of 3D laser scanning can lead to a 5-7% reduction in project costs and 10-12% improvement in project timing[85], with up to 80% reduction in sitetime[86], hence representing a significant improvement over the long run if consistently used.

Figure 16: 3D Scan's growth in interest (2015-2020)[87]



Source: Google Trends, 2020

When it comes to the construction phase of new buildings, 3D scanning is mainly used by architects and project managers in the design and construction phases. More specifically, 3D scanning is often combined with other sensors in specific drones to **survey and scan the area designated for the construction** (see Figure 18), so as to gather measurements and other data before and during the construction process. After scanning, the point-data **can be converted to a 3D model**. This allows to both adapt the design to the specificities of the building environment, and to obtain data to be integrated into BIM models and / or to create Digital Twins[88].

During the construction and maintenance phases, 3D scanning has a wide array of job site applications. For instance, 3D scans can be used by project managers and promoters to **compare the designed model** (BIM models) **with the current status of the construction**, so as to assess if everything is in line with the initial plan, or with the final outcome, to verify that the construction is compliant with the initial plan[89].

In the maintenance phase, 3D scanning can be combined with drones to **scan objects difficult to access** from the ground, such as bridges, railways and water constructions[90]. For instance, German railway company Deutsche Bahn uses 3D scanners to **survey the actual conditions of its infrastructures** so as to develop BIM models[91]. 3D scanning helps to digitally capture inventory for facility management, by quickly capturing body measurements and suggesting what is on site. The large number of data points results in high information content, which translates to more detailed imaging of complex objects[92]. For instance, thanks to the precise measures taken, Deutsche Bahn uses the data captured through 3D scanners to 3D print spare parts for its

85 Beroe. Adoption of 3D laser scanning proves beneficial for construction surveying. https://www.beroeinc.com/article/3d-laser-printing/
86 HistoricEngland. 3D Laster Scanning heritage. https://historicengland.org.uk/images-books/publications/3d-laser-scanning-heritage/heag155-3d-laser-scanning/
87 The map is based on the analysis of Google research data. Countries coloured in grey are those for which no data was available.
88 Builder Space. 13 benefits of laser scanning in Construction. https://www.builderspace.com/13-benefits-of-laser-scanning-in-construction
89 UK Construction Media. 3 Key benefits of 3D Laser Scanning. https://www.ukconstructionmedia.co.uk/features/3-key-benefits-3d-laser-scanning/
90 Geo4Construction. Using Drones in Construction for Aerial Inspection Photogrammetry or Lidar. https://www.geo4construction.com/news/using-drones-in-construction-for-aerial-inspection-photogrammetry-or-lidar
91 Deutsche Bahn. Vorgaben zur Anwendung der BIM-Methodik. https://www1.deutschebahn.com/resource/blob/1786332/1c0d47f32e6d4a8e221a7019f5fdb4ce/Vorgaben-zur-Anwendung-der-BIM-Methodik-data.pdf
92 LaserScanning Europe. Construction and Architecture. https://www.laserscanning-europe.com/en/content/construction-and-architecture

infrastructures or machines[93]. 3D scanners are also used in the real estate sector for documentation and surveillance in building projects, as well as for the registration and **documentation of existing buildings**.

Figure 17: Example of the use of 3D Scanning to preserve Europe's wooden built heritage[94]

Figure 18: Italian start-up Gexcel[95], in cooperation with the European JRC, has developed a backpack equipped with a 3D scanner for rapid mapping of indoor and outdoor sites

2.2.2 Automating processes

This section refers to the use of automation technologies (robots, 3D printers, and drones) to execute specific tasks in the broad construction process without the need for direct human labour input or instruction[96].

2.2.2.1 Robotics

Robots are devices that execute specific operations (i.e. lay tiles, lift objects, etc.), either autonomously (i.e. under pre-determined reiterative instructions) or under an operator's direct control.

The use of robots on construction sites is still very limited, and the market adoption is at the infancy stage[97,98], but **robotics production market is predicted to grow steadily over the next few years.** Figure 19 below shows the responses to the survey conducted for this report. Most of the respondents were not aware of the adoption rate of robotics in the construction sector in their MS, broadly in line with the findings from the analysis of Google trends, which showed a modest growth in the overall awareness of this technology (see Figure 21). Those who responded to the survey stated that robotics is used either to a small extent or not at all in their country. It is further evidence of the infant status of this technology in the construction sector.

93 Deutsche Bahn. Deutsche Bahn goes additive with Bigrep. https://bigrep.com/wp-content/uploads/2018/08/DB_eBook.pdf

94 European Commission. Preserving Wooden Heritage. Methods for monitoring wooden structures: 3D laser scanner survey and application of BIM systems on point cloud models. https://cordis.europa.eu/project/id/746215

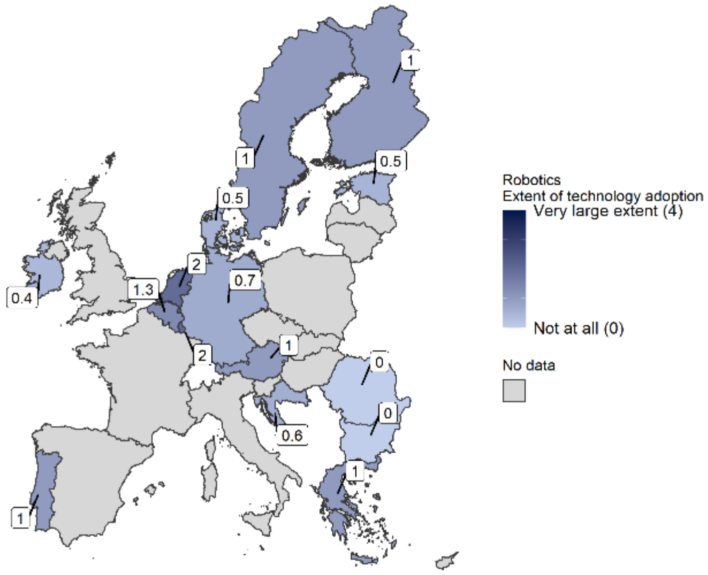
95 Gexcel. HERON. https://gexcel.it/en/solutions/heron-mobile-mapping

96 JRC (2019). Digital Transformation in Transport, Construction, Energy, Government and Public Administration.

97 Information based on the survey. ECSO survey results are not statistically representative and should be interpreted accordingly.

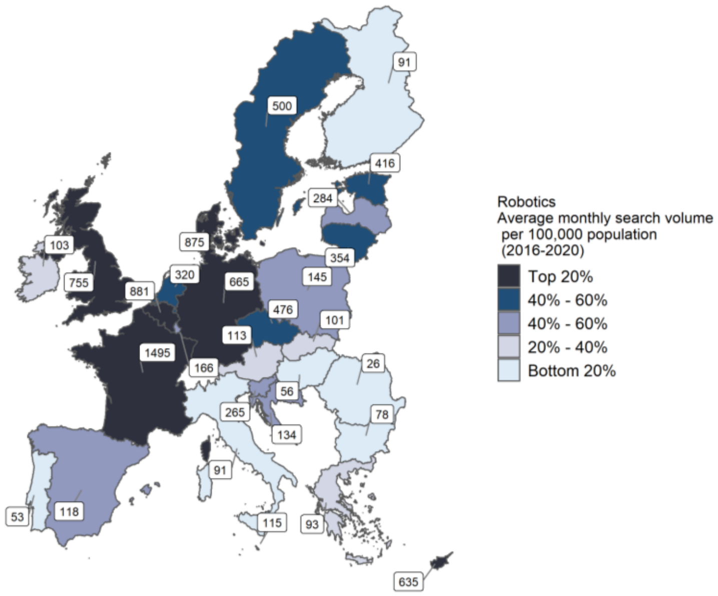
98 Delgado, J.M.D.; Oyedele, L.;Ajayi, A.; Akanbi, L.; Akinade, O.; Bilal, M.; Owolabi, H. (2019). Robotics and automated systems in construction: Understanding industry-specific challenges for adoption. Journal of Building Engineering 26.

Figure 19: Adoption extent of Robotics in EU MS[99]



Source: ECSO survey, 2020

Figure 20: Average monthly Robotics search volume (2016-2020)[102]



Source: Google Ads, 2020

Exoskeletons are expected to have the fastest increase is their development compared to other technologies (i.e. metal frameworks equipped with motorised parts that on-site workers wear[100] to help with repetitive and/or difficult tasks). Furthermore, **"robotics and automation" is the third most requested technical skill to Digital Innovation Hubs** (with a frequency of 65%[101]).

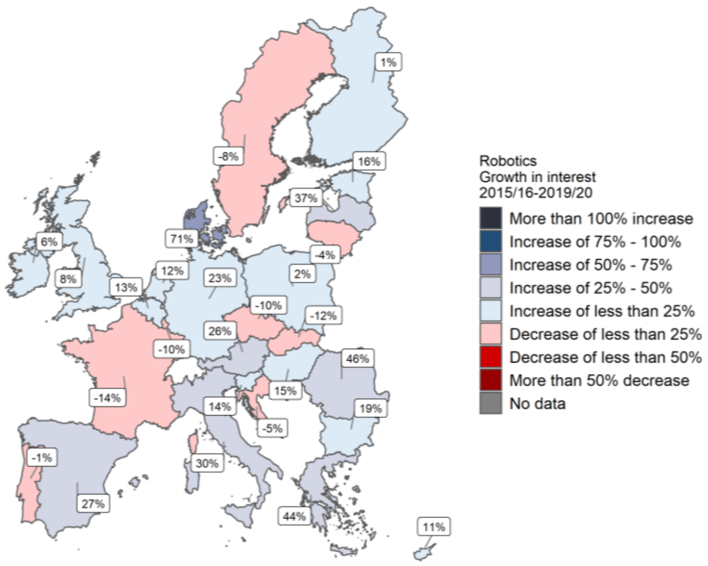
According to the latest estimations, the European Building Automation Systems (BAS) market is projected to grow at a pace of 2.6% per annum between 2018 and 2025[103]. Although not exponential, these trends show a progressive evolution of this technology. The trend is in line with the general **increased interest in robotics**, which experienced an average annual growth of 3% between 2015 and 2020, with an overall growth of around 13.3% for the whole period. By analysing Google trends data that refers to online searches on robotics[104], it is clear that France had the highest number, which remained relatively stable throughout the selected period (Figure 20). Most of the other MS have shown moderate interest in robotics and the amount of online searches has grown only moderately, with a few exceptions in Sweden, Czech Republic, Slovakia, Croatia, and Lithuania (Figure 21).

The scope of robotics in construction is broad, encompassing the majority of the stages of construction, from initial construction, to its operation and maintenance, to the eventual dismantling and recycling.

99 The map is based on survey results. 37 participants responded to this question. Countries coloured in grey are those for which no data was available. ECSO survey results are not statistically representative and should be interpreted accordingly.
100 Constructible, Exoskeletons for Construction Workers Are Marching On-Site. https://constructible.trimble.com/construction-industry/exoskeletons-for-construction-workers-are-marching-on-site
101 Ibidem.
102 The map is based on the analysis of Google research data. Countries coloured in grey are those for which no data was available.
103 Frost & Sullivan. New Building Constructions and Strict Energy-Use Norms Fuel Demand for Building Automation Systems in Europe. https://ww2.frost.com/news/new-building-constructions-and-strict-energy-use-norms-fuel-demand-for-building-automation-systems-in-europe/
104 Data referring to all research conducted and not restricted to the construction sector alone.

Robots have multiple applications, mainly in the construction and maintenance phases. For example, in the construction phase, robots can deliver **more precise and uniform work.** They can replace human workers in tasks that involve difficult physical labour and / or presence in hazardous environments, or replace tasks that are repetitive. This leads to a two-fold added value. On the one side, it **reduces safety risks for workers**; On the other side, it significantly **reduces the possibility of mistakes**, including accidents[105].

Figure 21: Robotics' growth in interest (2015-2020)[106]



Source: Google Trends, 2020

In turn this translates to a **higher quality of construction, lower final costs and decreased likelihood of delays**. For instance, the use of **exoskeletons**, i.e. robotic body devices worn by the worker, can improve performance and significantly reduce safety risks when doing tasks such as lifting heavy loads, or using equipment in uncomfortable positions[107]. Robots could also be used to **motorise traditional physical activities**, such as brick laying, excavation, or wall painting[108]. This element would bring greater efficiency, better quality of work and less safety risks for on-site workers. These activities can also be automatised by being combined with other technologies, e.g. sensors, drones, and BIM, to execute the task without the need for physical human presence on the construction site[109].

During the **maintenance phase**, robotics can be used in **combination with other technologies** mentioned in this report, such as sensors or IoT. In this case, components of the physical building can be motorised and automated by combining sensors, software, and robotic elements. This could result in, for example, automatically closing and locking doors when nobody is home, or automatically opening a front gate when the owner's car is approaching, or adjusting the lighting, etc[110]. For instance, SPEXOR[111] (see Figure below) is a Horizon 2020 project focused on developing a spinal exoskeleton to prevent back pain and support workers in heavy physical tasks. The device is also equipped to conduct musculoskeletal stress monitoring, so as to regularly measure the worker's physical conditions. This is of particular relevance in the construction sector, where, according to the European Agency for Safety and Health at Work, 52% of construction workers report backaches, 54% show MSDs in the upper limbs, and 41% show them in the lower limbs[112]. Finally, automation can **increase productivity and work efficiency** by streamlining operations, thus reducing

105 Robotiq. How Robotics could change the future of Construction. https://blog.robotiq.com/how-robotics-could-change-the-future-of-construction
106 The map is based on the analysis of Google research data. Countries coloured in grey are those for which no data was available.
107 McKinsey. The impact and opportunities of automation in Construction. https://www.mckinsey.com/business-functions/operations/our-insights/the-impact-and-opportunities-of-automation-in-construction#
108 McKinsey. The impact and opportunities of automation in Construction.
109 Ibidem.
110 CNCB. Howe unlocking the potential of a smart building can reduce costs and boost business. https://www.cnbc.com/advertorial/2018/02/07/how-unlocking-the-potential-of-a-smart-building-can-reduce-cost-and-boost-business.html
111 Spexor. http://www.spexor.eu/
112 European Agency for Safety and Health at Work. Work-related musculoskeletal disorders: prevalence, costs and demographics in the EU. European Risk Observatory Report. https://osha.europa.eu/en/publications/msds-facts-and-figures-overview-prevalence-costs-and-demographics-msds-europe

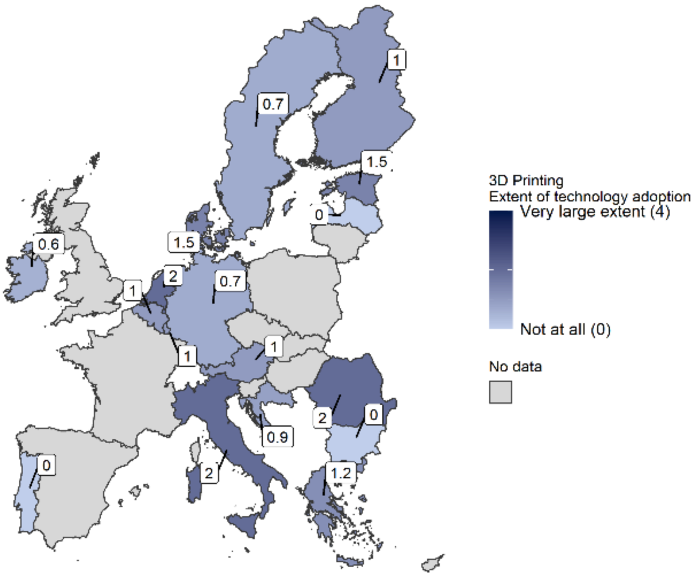
overall project costs[113] and maximising RoI. On average, it is estimated that incorporating BAS in the construction sector would result in up to 17% growth in resale value, 35% increase in rental rates, 18% higher occupancy rates, 30% lower operating expenses, and 9% higher net operating income[114].

Figure 22: Concept of Spexor[115]

Source: Spexor.eu

2.2.2.2 3D Printing

Figure 23: Extent of adoption of 3D Printing in EU MS[116]



Source: ECSO survey, 2020

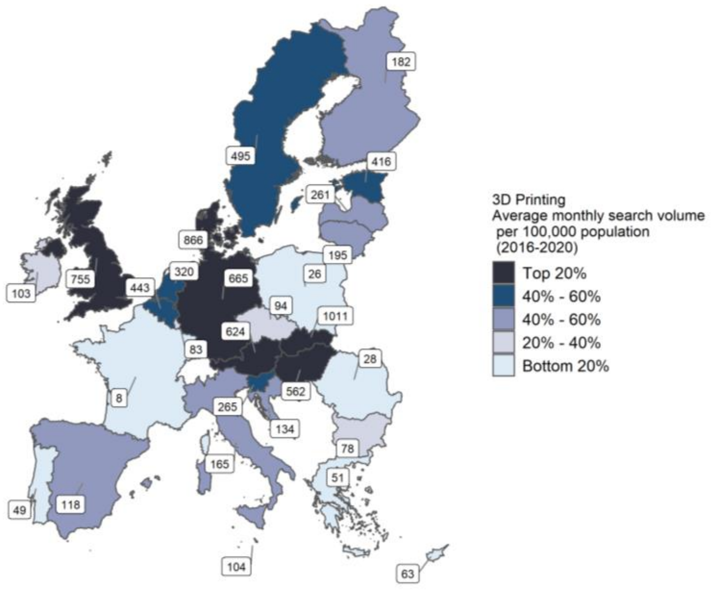
Additive manufacturing (hereinafter, 3D Printing) is the process of creating an object by adding layers of material (e.g. plastic, metal or concrete) upon one another under the control of a computer using a Computer-Aided Design (CAD) or BIM file to guide the 3D printer's nozzle[117].

Currently, the application of 3D Printing is limited to relatively **small scale applications** while the printing of larger parts and the use of more than one material are still a challenge[118,119]. Pilot projects on the use of 3D printing for an entire building have taken place (e.g. ETH in Zurich, Switzerland), but for the moment they remain uncommon. 3D printing is often combined with **laser cutting** machines. These machines cut a block of raw material (wood, steel, etc.)

113 Civil Engineer Portal. The use of automation in the construction Industry. https://www.engineeringcivil.com/the-use-of-automation-in-construction-industry.html
114 Frost & Sullivan. New Building Constructions and Strict Energy-Use Norms Fuel Demand for Building Automation Systems in Europe.
115 Spexor. http://www.spexor.eu/
116 The map is based on survey results. 44 participants responded to this question. Countries coloured in grey are those for which no data was available. ECSO survey results are not statistically representative and should be interpreted accordingly.
117 ECSO (2019), Supporting the digitalisation of construction and SMEs.
118 ECSO (2019), Supporting the digitalisation of construction and SMEs..
119 Craivero, F. et al. (2012). Automation for Building Manufacturing. Innovative Developments in Virtual and Physical Prototyping.

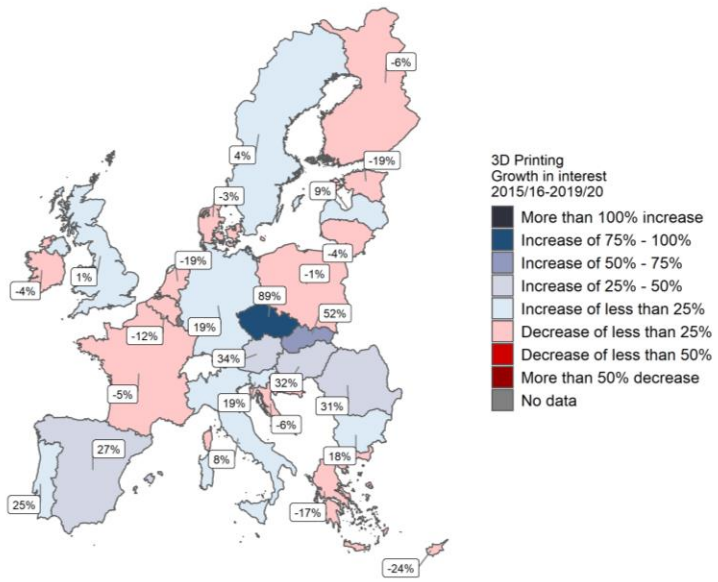
with laser rays into the final piece based on a pre-selected digital model[120]. While being two completely different construction processes, laser cutting can lead to similar outcomes as 3D printing and can also be applied in context where 3D printing still struggles to be used (e.g. wood elements).

Figure 24: Average monthly 3D Printing search volume (2016-2020)



Source: Google Ads, 2020

Figure 25: 3D Printing's growth in interest (2015-2020)



Source: Google trends, 2020

The role of 3D Printing occurs primarily in the construction phase, contributing to an overall construction cost reduction by using more time-efficient and material-efficient machines[121], thus also reducing the final amount of construction waste, particularly if used to produce modular elements. 3D-printed elements benefit from the characteristics of the material they are built from and are proven to be more durable, thanks to the way materials are produced and assembled[122].

For this reason, it is also used for building lightweight and energy efficient building facades and structural elements such as bridges (e.g. 3D-printed pedestrian bridge in Madrid, Spain).Furthermore, 3D printing can not only substitute traditional means of production, but can also achieve unique designs and shapes that are less attainable using traditional methods[123]. The use of 3D printers has also been found to be directly correlated to a reduction in injuries on construction sites[124].

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120 Filament2print, What laser cutting contributes to 3D printing. https://filament2print.com/gb/blog/67_laser-cutting-3d-printing.html

121 Construction Review Online. 7 Advantages of using a 3D printer in construction projects. https://constructionreviewonline.com/2020/04/7-advantages-of-using-a-3d-printer-in-construction-projects/

122 Giatec Scientific. How 3D Printing has transformed the Construction Industry. https://www.giatecscientific.com/education/8-ways-that-3d-printing-has-transformed-the-construction-industry/

123 ECSO (2019). Integrating digital innovations in the construction sector.

124 Ibidem.

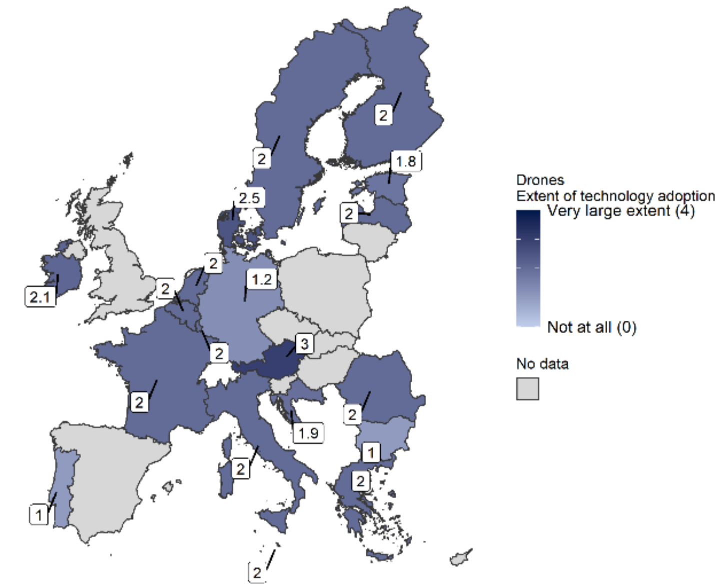
Figure 26: Italian company WASP has built one of the largest 3D printers in the world[125]. In the picture, the use of a clay-based 3D printer to build a sustainable house ("Tecla" project)

Source: 3D Swap, 2020.

2.2.2.3 Drones

Drones are aerial vehicles equipped with high-resolution cameras and other scanning equipment. Drones can provide live streaming videos and photos, which can be further elaborated through dedicated software to create 3D models, for instance, for BIM use. This also allows for reality-capture solutions and real-time comparison between planned and implemented solutions[127].

Figure 27: Extent of drones' adoption in EU MS[126]



Source: ECSO survey, 2020

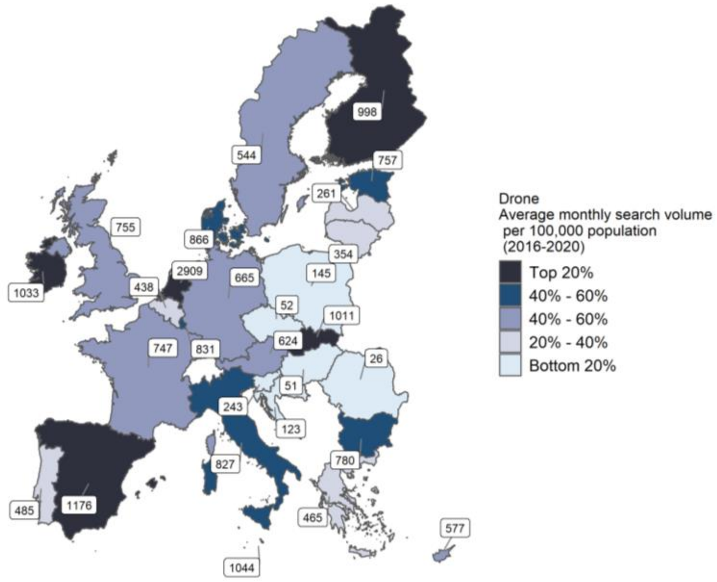
In the context of construction, drones are used by an increasing number of European construction companies[128] (around 21%[129]), with the utilisation being equally distributed across large-scale companies and SMEs[130]. This shows that that the upfront costs are not one of the main barriers to the adoption of this technology[131,132]. This is also explained by the fact that investments in drones in the

125 3DWasp (2020). 3D-printed house Tecla. https://www.3dwasp.com/en/3d-printed-house-tecla/
126 The map is based on survey results. 58 participants responded to this question. Countries coloured in grey are those for which no data was available. ECSO survey results are not statistically representative and should be interpreted accordingly.
127 ECSO (2019). Integrating digital innovations in the construction sector.
128 Information retrieved from interviews.
129 European Investment Bank (2019). Investment Survey 2019.
130 ECSO (2019). Integrating digital innovations in the construction sector.
131 Information based on the survey. ECSO survey results are not statistically representative and should be interpreted accordingly.
132 ECSO (2019). Integrating digital innovations in the construction sector.

construction sector have a very high added value[133], hence optimising RoI by decreasing costs and increasing efficiency and effectiveness during the execution of projects. The use of commercial drones in Europe (i.e. excluding military drones, toy drones and other drones for recreational activities) is expected to show a **significant market growth** in the current period 2018-2022 (+397.4% in revenues), to then stabilise in the period 2022-2025 (+143.2%)[134].

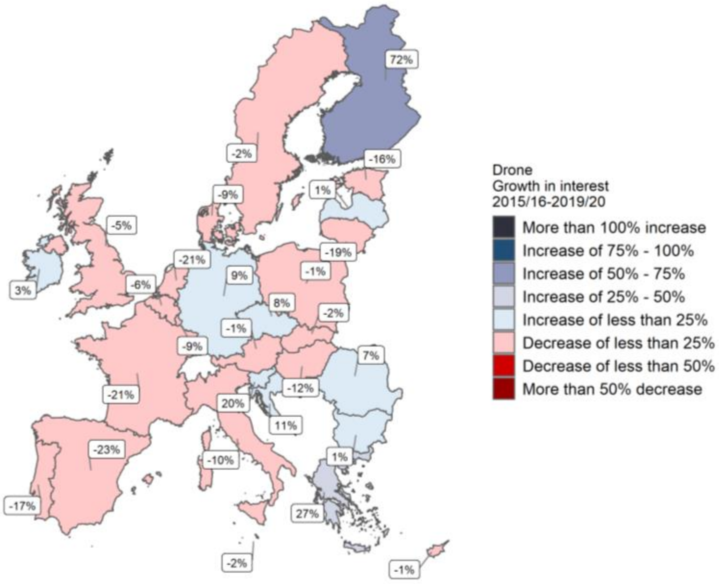
The growing utilisation of drones in the construction sector is reflected also in the results of the survey carried out for this report. As Figure 27 shows, drones have a moderate adoption rate across all MS[136], with Austria being the country with the highest adoption rate, according to the respondents to the survey.

Figure 28: Average monthly Drones search volume (2016-2020)[135]



Source: Google Ads, 2020

Figure 29: Drones' growth in interest (2015-2020)[138]



Source: Google Trends, 2020

The high interest in drones can be linked to their use in all stages of construction, from the pre-construction by providing field information for planners and real estate developers, to the final stages of a project, providing measures, photos, assessment and impact reports[137]. Indeed, drones increase efficiency and productivity in all these stages by surveying the site for progress, verifying contractor's reports, identifying discrepancies, and assisting in confirming compliance with regulations, in the case, for example, of the storage of materials or waste.

More specifically, drones are appreciated for their capacity to support in an efficient and inexpensive way the mapping of construction sites with exact coordinates and values. They can be used to capture an aerial view of a site, and this data can then converted to a 3D model. This can be faster and cheaper than other techniques, and also decreases risk by removing the requirement for surveyors to work in danger (e.g. at height, or near

133 Blanca de Miguel Molina and Marival Segarra Oña. The drone Sector in Europe, Ethics and Civil Drones.
134 Ibidem.
135 The map is based on the analysis of Google research data. Countries coloured in grey are those for which no data was available.
136 Excluding Member States for which no replies were given.
137 ECSO (2019). Integrating digital innovations in the construction sector.
138 The map is based on the analysis of Google research data. Countries coloured in grey are those for which no data was available.

hazards)[139]. This also allows stakeholders to have precise digital representation of the construction site, following the type of sensors installed on the drone (e.g. heat sensors for thermal imaging, volumetric sensors)[140]. The added value of drones relies not only on the data gathering per se, but also on their ability to **access to areas particularly challenging** for traditional machineries (e.g. structures built over water, roofs, etc.)[141]. Drones can also improve **communication and management activities** by providing precise real-time data that can be exchanged between different actors, thus reducing the time required for implementing changes and assessing the progresses of the work.

Figure 30: German company h-aero has developed drones that can be used to scan, stock-take and inspect tunnels, power plants, and other sites[142]

Figure 31: The benefits of drones in Construction[143]

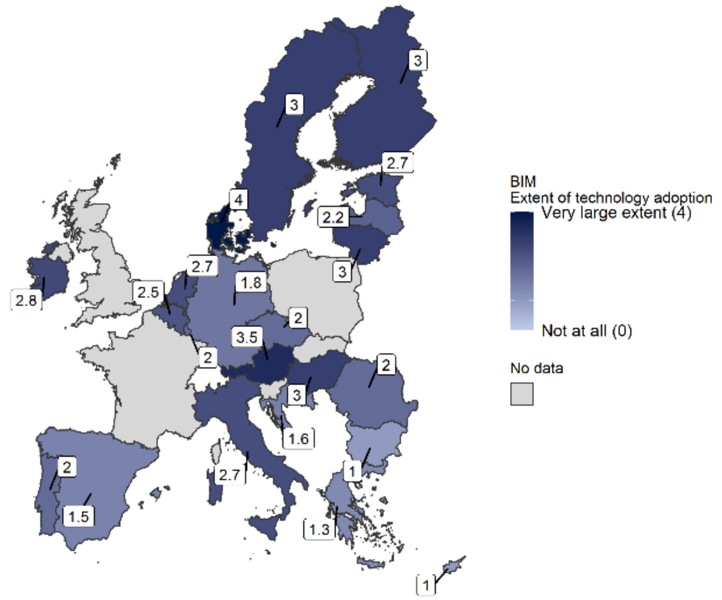
Source: DroneDeploy (2018)

139 HSE, Improving Health and Safety Outcomes in Construction. Making the Case for Building Information Modelling (BIM).
140 Information retrieved from the interviews.
141 Construction Review Online. Utilizing drone technology in Construction. https://constructionreviewonline.com/2018/03/drones-in-construction/
142 H-aero. https://h-aero.com/en/
143 DroneDeploy, Trends Report 2018

2.2.3 Digital transformation and analysis

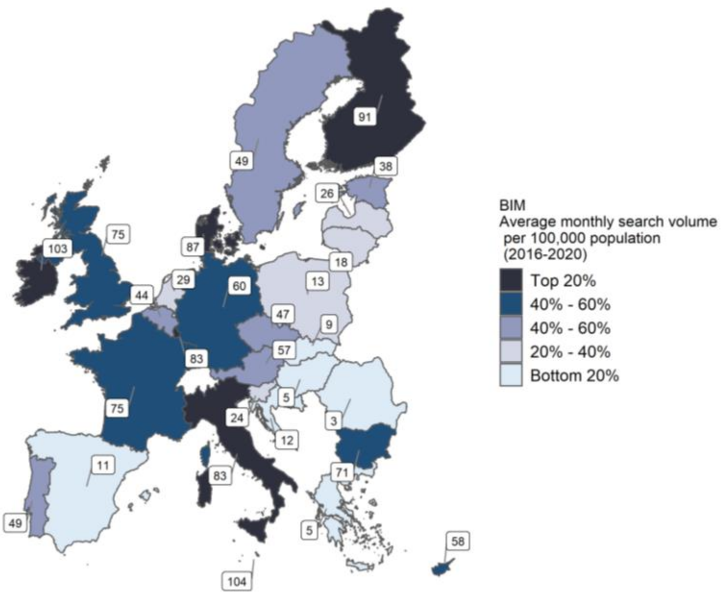
2.2.3.1 BIM

Figure 32: Extent of BIM adoption in EU MS[144]



Source: ECSO survey, 2020

Figure 33: Average monthly BIM search volume (2016-2020)[145]



Source: Google Ads, 2020

Building Information Modelling (BIM) is a digital form of construction and asset operations. It brings together technology, process improvements and digital information to radically improve client and project outcomes and asset operations[146]. BIM is a strategic enabler, improving decision making for both buildings and public infrastructure assets across the whole lifecycle. It applies to new build projects; and crucially, BIM supports the renovation, refurbishment and maintenance of the built environment – the largest share of the sector[147]. It can be combined with geospatial data, algorithms and other data analysis software to further expand its potential (see 'Geographic Information Systems' and 'Parametric and Generative Design' sections below). There are different 'dimensions' of BIM, depending on the type of information included. More specifically[148]:

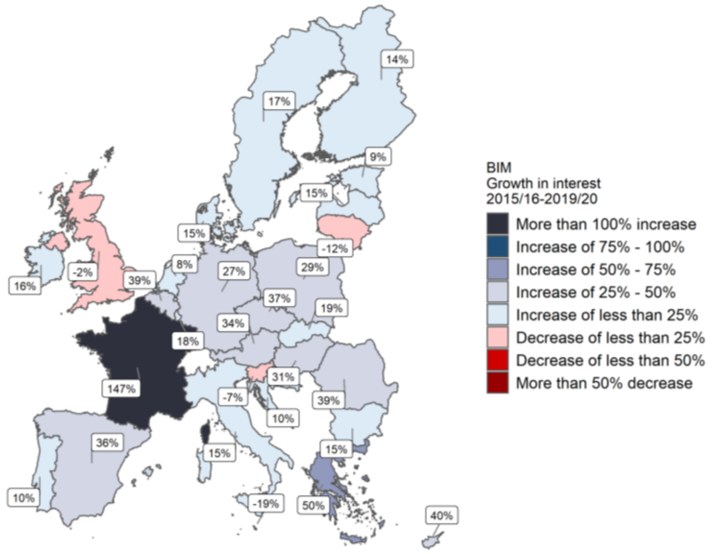
- BIM 3D contains the three-dimensional data (height, length, and depth) of the structure;
- BIM 4D includes also time data (duration, scheduling, etc.);
- BIM 5D adds information concerning costs;
- BIM 6D includes sustainability data (e.g. in terms of energy efficiency); and
- BIM 7D includes, in addition to all the data of the previous dimensions, also facility management information.

The European Commission has long supported the adoption of BIM, particularly in public procurement by promoting and

[144] The map is based on survey results. 87 participants responded to this question. Countries coloured in grey are those for which no data was available. ECSO survey results are not statistically representative and should be interpreted accordingly.
[145] The map is based on the analysis of Google research data. Countries coloured in grey are those for which no data was available.
[146] ECSO (2019). Building Information Modelling in the EU construction sector.
[147] ECSO (2019). Building Information Modelling in the EU construction sector.
[148] United BIM. What are the BIM dimensions. https://www.united-bim.com/what-are-bim-dimensions-3d-4d-5d-6d-7d-bim-explained-definition-benefits/

developing several policies and initiatives aiming to foster the digitalisation in the construction sector (see section "3. Digitalisation policies and initiatives in the EU" below).

Figure 34: BIM's growth in interest (2015-2020)[149]



Source: Google Trends, 2020

BIM is arguably the most developed and used digital technology in the construction sector; however, **its market adoption in the EU is still moderate**[150]. In fact, in Europe, 29% of construction companies uses BIM 3D (which includes information sharing and the creation of graphical and non-graphical information); while 61% have never used it[151]. The numbers drop considerably concerning BIM 4D with only 6% of companies implementing it.

Figure 32 shows the level of BIM adoption in EU MS based on the responses to the survey. With the exception of a few countries for which no responses were available in the survey executed as part of this study, there is a relatively high average adoption rate of BIM. Denmark and Austria are the countries with the highest adoptions[152], but all MS reported a degree of BIM usage. The results from the survey can be supplemented with other studies on BIM adoption in the EU. In France, in 2017, 38% of companies in the construction sector stated that they are using BIM, with engineers showing a higher-than-average adoption rate (44%)[153]. On the contrary, Poland reports a more modest level of BIM adoption, with only 12% of construction companies using it[154]. BIM adoption across EU MS is also linked to the legislative framework in place. For instance, Austria and the Netherlands are the only two MS with Open BIM[155] standard mandate[156], while several Member States have either a BIM requirement in their public procurement processes applying to all projects or projects of certain thresholds, scope of type (e.g. infrastructure).

A few countries, like Portugal and Belgium, do not currently have a state-wide BIM mandate planned[157]; however, this does not prevent BIM mandates at the regional or urban levels and is not necessarily a correlation of low BIM adoption (see 3.2.2 BIM in public procurement for more information).

The European BIM market was valued at EUR 1.8 billion in 2016 and predicted to grow by 13% to reach EUR 2.1 billion in 2023[158]. At the global level, the BIM market is expected to grow by 18% annually from 2019

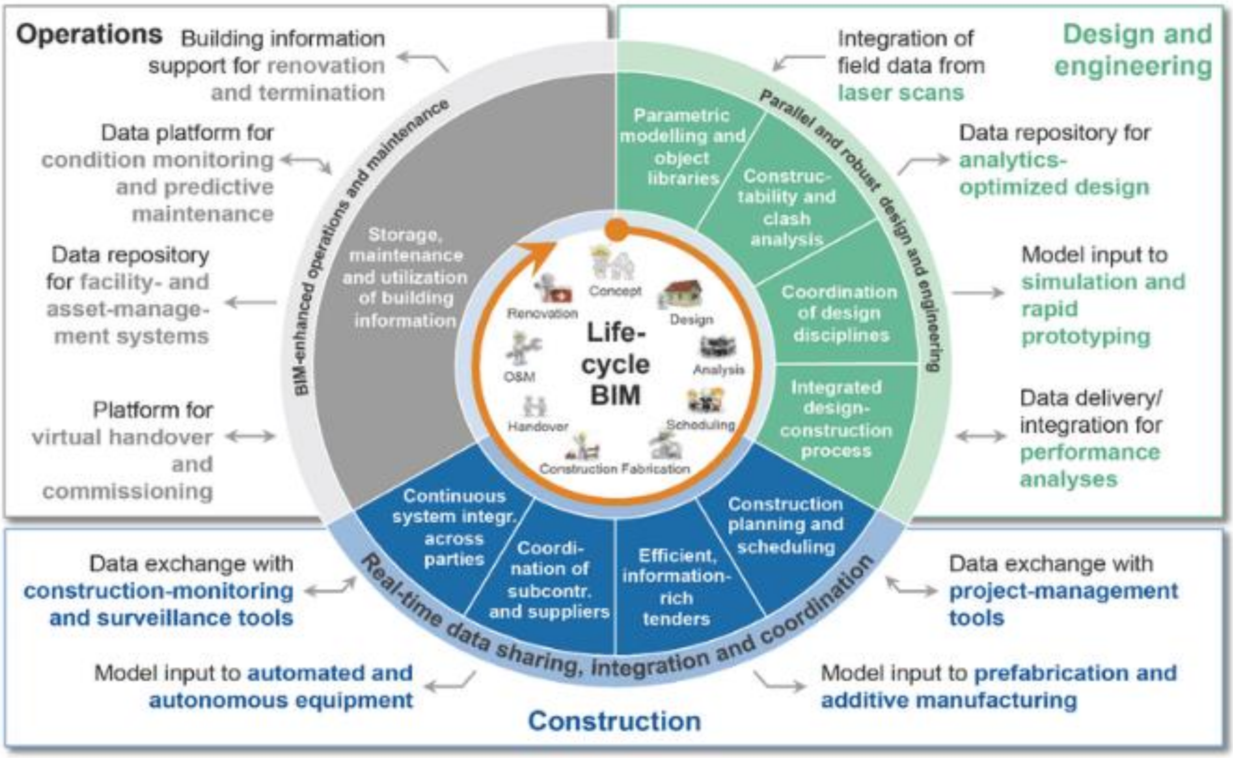
149 The map is based on the analysis of Google research data. Countries coloured in grey are those for which no data was available.
150 Information based on the survey. ECSO survey results are not statistically representative and should be interpreted accordingly.
151 ECSO (2019). Building Information Modelling in the EU construction sector.
152 Information based on the survey. ECSO survey results are not statistically representative and should be interpreted accordingly.
153 ECSO (2019). Building Information Modelling in the EU construction sector.
154 Ibidem.
155 "OpenBIM extends the benefits of BIM by improving the accessibility, usability, management and sustainability of digital data in the built asset industry. At its core, openBIM is a collaborative process that is vendor-neutral. openBIM processes can be defined as sharable project information that supports seamless collaboration for all project participants. openBIM facilitates interoperability to benefit projects and assets throughout their lifecycle". Definition retrieved from: https://www.buildingsmart.org/about/openbim/
156 MagiCAD. The different phases of BIM adoption in Europe. https://www.magicad.com/en/blog/2020/03/bim-adoption-europe/
157 Ibidem.
158 ECSO (2019). Building Information Modelling in the EU construction sector .

to 2027[159]. Future BIM developments are expected to include real-time integration of sensor data in smart buildings to create a fully functioning virtual living model of the construction project, including information on the status of possible damage and malfunctioning[160] (see also “2.2.3.2 Digital Twins” below). Regardless, the interest in the technology is very high, particularly in France, Germany, and Italy, and has seen a notable increase of 23.9% in the period 2015-2020, spread evenly across all EU Member States, with France as the frontrunner (see Figures below).

BIM fragmented adoption is due to the market structure and the sizes of companies[161]. In fact, BIM implementation is mainly led by large companies, with SMEs showing limited BIM adoption[162]. This is partly explained by three factors. First, larger companies have more financial and human resources to implement BIM[163]. The very high initial costs and skilled workforce, that are required, have been assessed as the main cause for its slow adoption[164]. Second, larger companies tend to take on more complex projects, where strong coordination is required. The complexity makes the benefits of BIM more tangible, thus justifying the initial investment required[165]. Some reports also pointed out the lack of demand from project promoters, mainly due to the lack of awareness of BIM benefits[166]. **BIM can bring numerous benefits and advantages to the construction sector and to all stakeholders involved in the construction lifecycle, particularly for architects, project promoters and facility managers, as it serves as the central software platform to integrate design, modelling, planning, and collaboration**, thereby providing a digital representation of a building's characteristics throughout its lifecycle[167]. Indeed, measurable benefits could be brought to the construction and post-occupancy management of assets (buildings and infrastructure) through the increased use of the BIM methodologies[168]. However, despite its applicability during the entire construction process (see Figure below), **BIM is currently mainly used in design and construction phases**, with lower adoption rates in the operations and maintenance phases[169].

159 GlobeNewsWire. Building Information Modeling Market (BIM) Size & Share Will Reach USD 15,700 Million, Globally By 2026: Facts & Factors. https://www.globenewswire.com/news-release/2021/01/22/2162854/0/en/Building-Information-Modeling-Market-BIM-Size-Share-Will-Reach-USD-15-700-Million-Globally-By-2026-Facts-Factors.html
160 European Commission, JRC Science for Policy Report.
161 ECSO, Building Information Modelling in the EU construction sector
162 Ibidem.
163 Ibidem.
164 European Commission, JRC Science for Policy Report.
165 ECSO, Building Information Modelling in the EU construction sector
166 McGraw Hill Construction, The Business Value of BIM for Owners. https://i2sl.org/elibrary/documents/Business_Value_of_BIM_for_Owners_SMR_(2014).pdf
167 European Commission, JRC Science for Policy Report.
168 HSE, Improving Health and Safety Outcomes in Construction. Making the Case for Building Information Modelling (BIM).
169 ESCO, Building Information Modelling in the EU construction sector.

Figure 35: Application of BIM to the entire construction value chain[170]



BIM has been developing rapidly, primarily thanks to the significant advantages it provides to its users. During the design phase, solutions can be configured and assessed without exposing workers to risk and BIM objects can be used in planning health and safety measures and logistics on site[171]. By supporting an improved flow of information between all stakeholders, with **reduced possibilities of information loss**, BIM **facilitates the collaboration** between different stakeholders and throughout the project phases[172]. In this context, the EU-funded **BIMplement**[173] project provided trainings and BIM related upskilling activities to help different professions collaborate through BIM in the construction of Nearly-Zero-Energy-Buildings (nZEB). To do so, the project established a “BIM-enhanced Qualification Framework” that described the competences, skills and knowledge that professionals need to develop BIM models and construction processes[174].

BIM contributes to important efficiency gains, lower costs, lower possibility of mistakes, faster delivery with less miscommunication, inaccuracies and delays, growing business opportunities and lower emissions and waste[175]. BIM is of most relevance for large, complex and integrated infrastructure projects, involving a wide range of activities and stakeholders; its benefits are, nonetheless, also relevant for smaller projects. Different studies suggest that BIM implementation in construction projects can reduce overall costs by around 7%, with benefits particularly concentrated in the construction phase[176]. Nonetheless, significant benefits can

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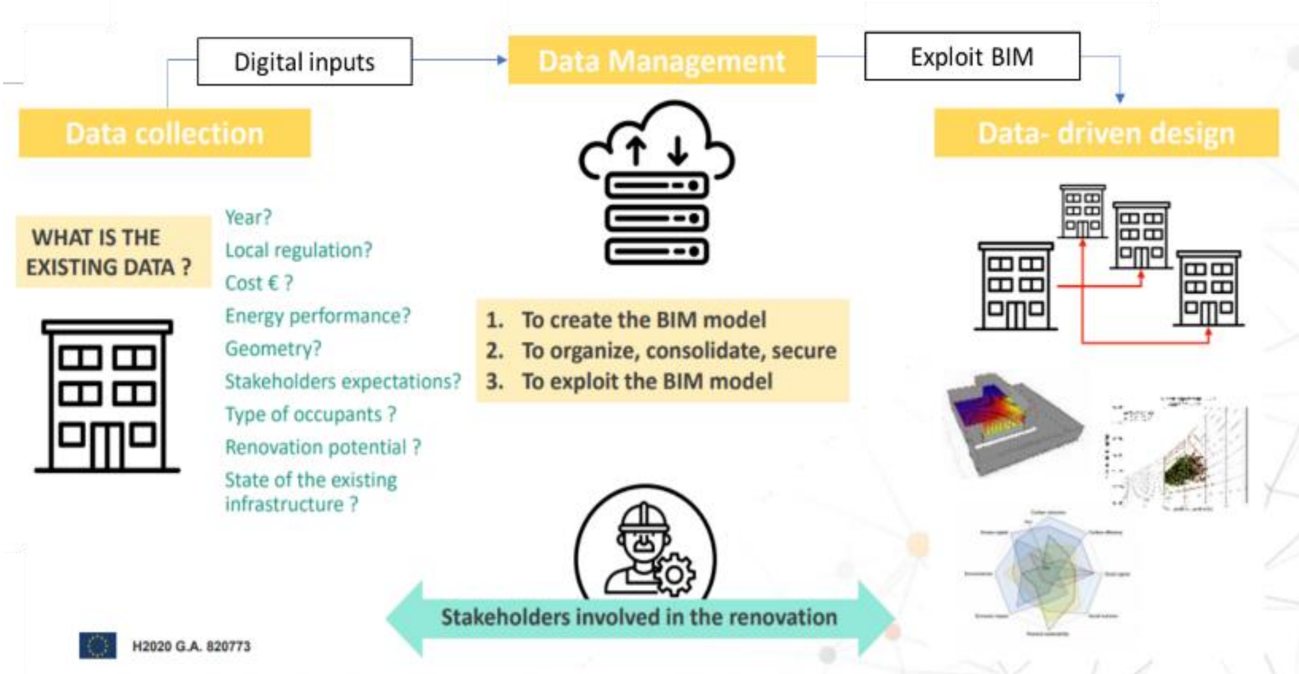
170 European Commission, Building Information Modelling (BIM) standardization.
171 HSE, Improving Health and Safety Outcomes in Construction. Making the Case for Building Information Modelling (BIM).
172 Yang, Y.; Jiang, Y. (2015). Research on the Impacts of BIM on Information Exchange between Stakeholders in Construction Project.
173 For more information: https://www.bimplement-project.eu/
174 Ibidem.
175 Autodesk BIM 360, Top 10 Benefits of BIM in Construction. https://bim360resources.autodesk.com/connect-and-construct/top-10-benefits-of-bim-in-construction
176 Lu, W.; Peng, Y.; Liang, C.; Fung, A. (2014). Cost-benefit analysis of Building Information Modelling implementation in building projects through demystification of time-effort distribution curves. Building and Environment (82): 317–327.

also be achieved in the other phases, such as a 15% saving in planning, risk assessment, safety and assurance costs[177], waste production reduced by up to 15%, and construction waste management costs by up to 57%[178]. Indeed, 75% of companies adopting BIM reported positive returns on their investment with shorter project life cycles and savings on paperwork and material costs[179]. To further develop the benefits, **BIM-SPEED project**[180], funded under Horizon 2020, has the goal of using BIM to reduce the time of deep renovation projects for energy efficiency by at least 30%. This is planned to be achieved by providing affordable cloud platforms, interoperable BIM tools, and standardised procedures for data acquisition, modelling, simulation and implementation[181]. Indeed, BIM can also be used during the renovation phase to, for example, increase the energy efficiency of the building. Figure 36 shows the concept of **BIM4Ren**[182], another Horizon2020 project, on the use of BIM for the energy renovation of existing buildings for the entire construction value chain.

Figure 36: BIM4Ren concept[183]. Exploitation of BIM potential for the energy renovation of existing buildings for the whole construction value chain



Some trends are emerging in regard to the use of BIM, and in particular in its combination with other digital solutions. For instance, BIM models can be used to 3D print specific construction parts using various materials (see section 2.2.2.2 3D Printing), or it can be integrated with information gathered through sensors to visualise architectural elements before building them (2.2.3.3 Virtual and augmented reality), which turns particularly useful for larger infrastructural projects. For example, the Estonian company **InfraBIM**[184] is specialised in 3D visualisation of large-scale projects based on BIM data, which allows construction professionals to visualise the project before building it.

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177 HSE, Improving Health and Safety Outcomes in Construction. Making the Case for Building Information Modelling (BIM).
178 Zoghi, M.; Kim, S. (2020). Dynamic Modelling for Life Cycle Cost Analysis of BIM-Based Construction Waste Management.
179 ESCO, Building Information Modelling in the EU construction sector.
180 European Commission. Harmonised Building Information Speedway for Energy-Efficient Renovation. https://cordis.europa.eu/project/id/820553; https://www.bim-speed.eu/en
181 Ibidem.
182 For more information: https://bim4ren.eu/
183 Taken from BIM4Ren. https://bim4ren.eu/
184 For more information: http://www.infrabim.ee/

BIM can also be used to develop and update a Digital Twin (see 2.2.3.2 Digital Twins). Furthermore, Geographic Information Systems (GIS) and parametric / generative design are specific methods linked to BIM models for specialised usages. For instance, the integration of BIM and GIS allows for the introduction of geospatial data into BIM models, and the use of parametric and generative design allows for real-time and automatic updates of BIM models. Below, a brief description of GIS, Parametric and Generative design as specialised implementations of BIM models is provided.

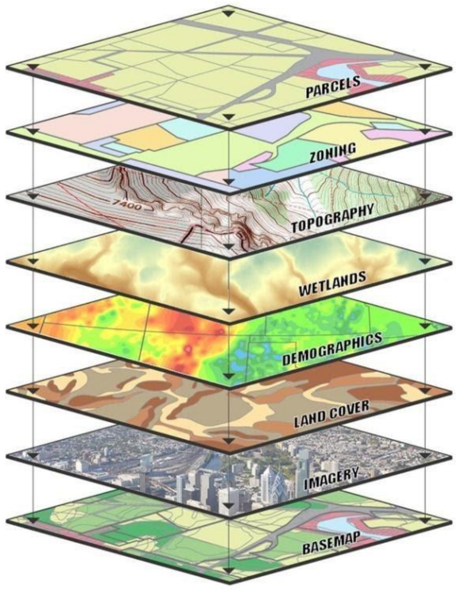
Geographic Information System

Geographic information systems (GIS) **allow data to be captured, mapped, stored and visualised according to its location in space and time.** GIS and BIM are highly interrelated, as BIM may use data from GIS, such as site information and spatial analysis, and may produce data useful for GIS, such as energy performance data[185]. GIS modelling can be used to **generate and update planning and databases with geospatial data** and within a single integrated platform, which is a significant potential benefit for the construction sector. Combining GIS data with its surrounding topography by linking 2D / 3D drawings and databases of activities or components of a building, allows more precise and complete designs, which result in safer and more efficient execution of the construction activities. The combination of data provides greater control over the project delivery process[186], prevents duplication and allows complementary data from different sources[187].

In the construction sector, GIS is useful as it **contextualises BIM models into the surroundings** where they will be built, with an even greater added value for unusual locations. In this way, it can provide stakeholders, project managers, construction engineers and contractors with additional data on the building during its entire lifecycle, as it provides information on, for instance, flood-prone areas, sun exposure etc[188].

GIS generally operates at a larger scale than BIM and **locates data across a topography**, therefore being particularly suited for urban planning and the design of smart cities. Geospatial data from GIS can concern the urban built environment, public spaces, green spaces, water sources and quality, electric grid, transport infrastructure, etc. The merger of topographic data with BIM models provides urban planners with the possibility to develop urban digital models, to visualise and analyse the user-friendliness of the urban environment[189]. Some EU MS have already started including GIS data into their construction platforms. For more information, refer to 3.2.5 Digital building logbooks and digital registries.

Figure 37: Geographic Information System concept



Source: usgs.gov

Parametric and Generative Design

Parametric design is an interactive process that allows designers, architects and project promoters to create designs based on the input of parameters, such as materials, site constraints, and even

185 DesignBuildings, Geographic Information Systems (GIS). https://www.designingbuildings.co.uk/wiki/Geographic_information_system_GIS
186 Bonsu, H. A. Application of GIS in building construction.
187 Geospatial world, GIS Technologies in Construction. https://www.geospatialworld.net/article/gis-technologies-in-construction/
188 GISLounge, GIS and BIM integration in Infrastructure design and Construction. https://www.gislounge.com/gis-and-bim-integration-in-infrastructure-design-and-construction/
189 GIM International, USE of GIS in Smart City Projects. https://www.gim-international.com/content/article/use-of-gis-in-smart-city-projects

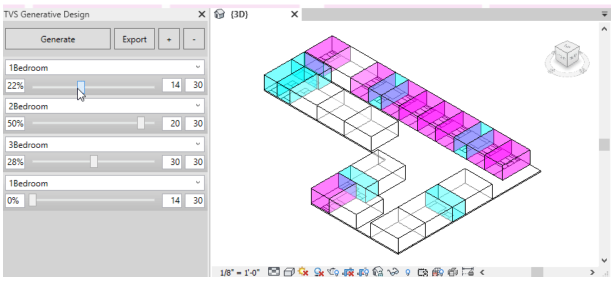
environmental requirements. Changes to the framework conditions automatically lead to the components of a BIM model being updated[190]. This removes the possibility of calculation errors from workers and significantly reduces the time required to update designs (compared to making changes manually). As drawings are derived from the BIM model, layouts can be regenerated rapidly and with little effort with every change[191]. This approach allows architects and engineers to explore many options before deciding on the final design, as the software makes changes to the project in real-time and automatically updates the design. Today, parametric methods are used in many different applications like bionic construction, lightweight construction, modular construction, and infrastructure construction. The figure below shows the Alvar Aalto Museum in Finland, whose bamboo structure was obtained through a computational and mathematical process[192].

Figure 38: Alvar Aalto Museum, Finland

Source: rat-lab.org

Generative design is an iterative technique that uses advanced algorithms to increase the designer's ability to define, explore, and choose alternatives through automation by ranking the outputs based on a pre-defined set of criteria provided by the designer. This allows to automate the elaboration of large amounts of complex data, thus saving time, reducing the likelihood of errors, and increasing accuracy[193]. Generative techniques are useful not only during the design phase, but, if provided with the right amount and type of data, also during the construction phase. Generative software can experiment with a multiplicity of options looking for the most efficient process to build (e.g. positions of the trucks for delivery of panels based on their weight, final place, access points)[194]. In Azerbaijan, the Heydar Aliyev Centre[195] is an example of a building designed with a generative technique: dedicated software made possible to come up with a final shape that aligned all the pre-selected design parameters.

Figure 39: EvolveLAB's iterative planning tool



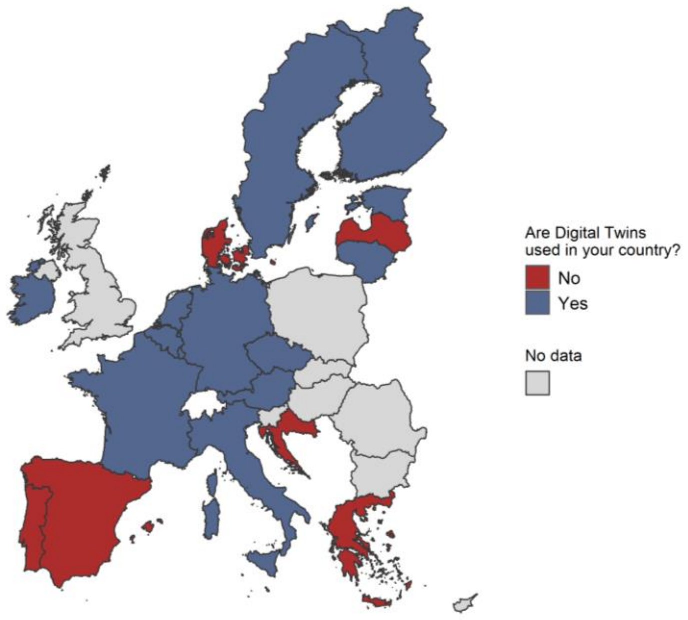
Source: evolvelab.io

[190] Allplan, Parametric BIM Modelling. https://blog.allplan.com/en/parametric-bim-modeling
[191] Allplan, Parametric BIM Modelling. https://blog.allplan.com/en/parametric-bim-modeling
[192] For more information: https://www.rat-lab.org/alvar-aalto-museum
[193] Archistar, Parametric Design vs Generative Design - the Pros and Cons. https://archistar.ai/blog/parametric-design-vs-generative-design-the-pros-and-cons/
[194] RedShift, Generative Design Architecture. https://redshift.autodesk.com/generative-design-architecture/
[195] More information at: https://www.zaha-hadid.com/architecture/heydar-aliyev-centre/

Today, generative design and parametric design are mainly used during the design phase, but their adoption is expected to grow exponentially over the course of the next few years, in parallel with the increased digitalisation of the construction sector and, consequently, the availability of more construction data[196]. Parametric and Generative design will be more and more integrated with BIM models and Digital Twins. For instance, the company DiRoots[197] develops custom plug-ins for BIM software in order to standardise the development of designs and complex forms based on a series on parameters provided (e.g. automatically update the design of the lift based on the different data provided). The company EvolveLAB[198] developed a data-driven planning tool that generatively models the spaces in a BIM model (see Figure below).

2.2.3.2 Digital Twins

Figure 40: Utilisation of Digital Twins in EU MS[199]



Source: ECSO survey, 2020

A Digital Twin is the real-time digital representation of the physical building or infrastructure[200]. Usually, data is gathered by on-site sensors that continuously monitor changes in the building and in the environment and report back the updated state in the form of measurements, updated data and pictures, which are then processed by a dedicated software and updated in the Digital Twin[201]; this allows companies to continuously monitor progress against the schedule laid out in a 4D BIM model.

A Digital Twin differs from BIM for the amount and type of information it includes, as BIM models do not include real-time data collected directly from the construction site or building in operation, nor a track record of past issues and interventions[202]. For his reason, it is possible to say that BIM provides the basis for a Digital Twin, since it reproduces a broad set of characteristics that enable simulations of future behaviour; however, it does not provide direct physical-digital linkages and, as such, does not serve as a virtual operation tool[203]. Nonetheless, the two technologies can be combined on daily construction activities.

Given the nascent status of this innovative technology, there is not yet exhaustive data on the market adoption of Digital Twins, as they are **mainly used in pilot or experimental projects.** Figure 40 shows the use of Digital Twins in EU MS, based on the replies to the survey. Respondents to the survey confirmed that Digital Twins are present in most EU countries, but stakeholders consulted through dedicated interviews specified that most of the cases refer to pilot projects. However, it has been recognised that **Digital Twins**

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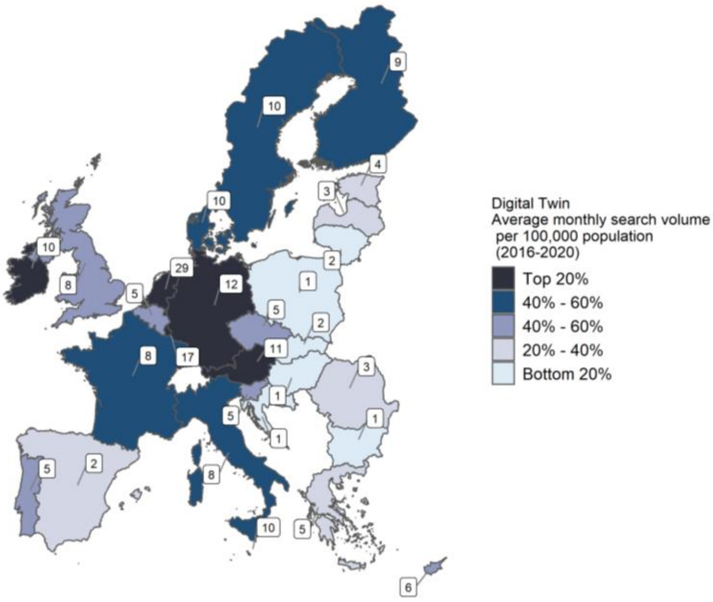
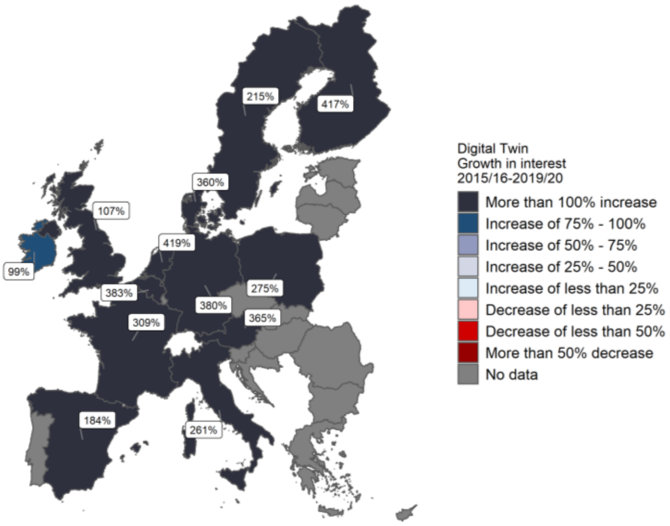
196 RedShift, Generative Design Architecture .
197 More information at: https://diroots.com/
198 More information at : https://www.evolvelab.io/
199 The map is based on survey results. 47 participants responded to this question. Countries coloured in grey are those for which no data was available. ECSO survey results are not statistically representative and should be interpreted accordingly.
200 LIST, Digital Twin. https://www.list.lu/en/institute/strategic-priorities/digital-twin/
201 IntellectSoft, Advanced imaging Algorithms for Digital Twin Reconstruction. https://www.intellectsoft.net/blog/advanced-imaging-algorithms-for-digital-twin-reconstruction/
202 European Commission, Digital Building Twins (RIA). https://cordis.europa.eu/programme/id/H2020_LC-EEB-08-2020
203 SPHERE. Digital Twin White Paper.

Figure 41: Average monthly Digital Twin search volume (2016-2020)[204]



Source: Google Ads, 2020

Figure 42: Digital Twin's growth in interest (2015-2020)



Source: Google Trends, 2020

are being increasingly used as they represent one of the most horizontal, useful and promising digital innovation in the sector. In fact, by analysing Google trends data, it is possible to notice a **significant increase in interest** in this technology, with an average +290% growth in interest across the EU. The Netherlands (+419%), Finland (+417%), Belgium (+383%), Germany (+380%), Austria, France, and Italy (+365%, 309%, and 261%, respectively) have reported the highest increase in online searches on Digital Twin over the 2015-2020 period. Ireland and Spain, on the contrary, have reported the lowest increases, which still account to +99% and +184%, respectively.

The benefits of using Digital Twins in the construction sector are multiple, mainly focused in the construction and maintenance phases, and primarily related to the kind of information fed into the Digital Twin model. During the construction phase, project managers and construction companies can leverage on Digital Twins to compare the initially planned time schedule laid out in the 4D BIM model with the actual situation on the construction site, thus allowing project managers to identify the deviations and divergences and promptly take actions[205]. By combining this technology with on-site sensors and / or drones, it is possible to constantly have real-time updates of the project, which allow for better management, timely identification of mistakes and, therefore, decreased possibility of delays.

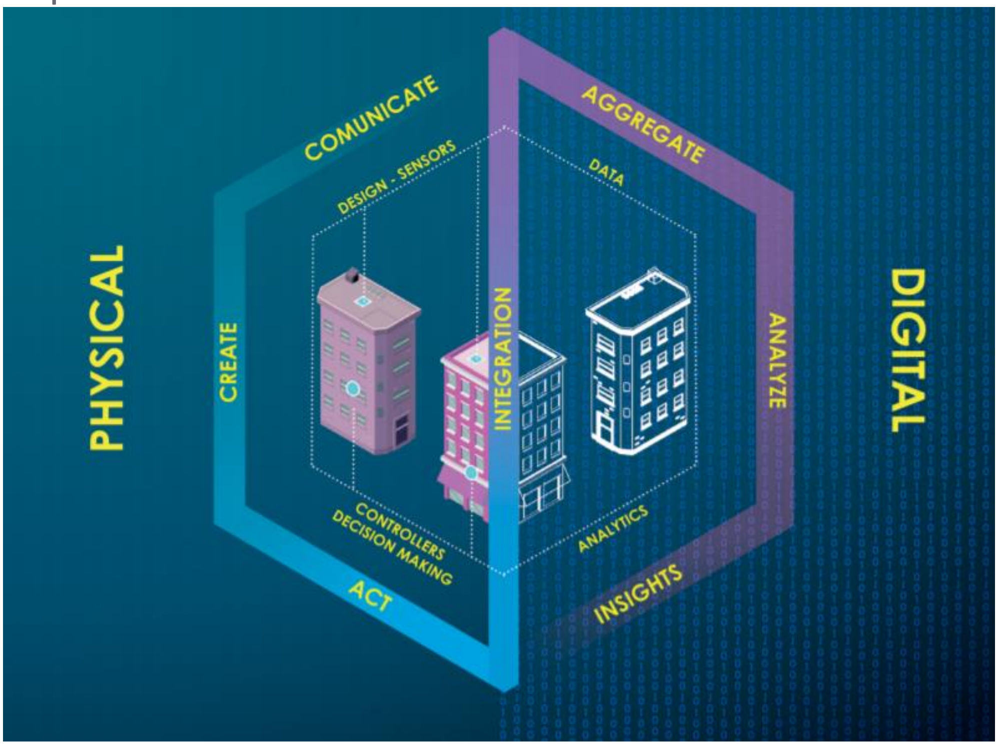
With Digital Twins companies can **avoid over-allocation** and **proactively predict resource needs on construction sites**, thus avoiding the need to move resources over long distances and improving time management[206]. Additionally, both during the construction and the maintenance phases, Digital Twins can provide automatic resource allocation monitoring and waste tracking, allowing for a predictive and **more efficient approach to resource management**. Buildings and entire neighbours can be kept regularly

204 The map is based on the analysis of Google research data. Countries coloured in grey are those for which no data was available.
205 Ibidem.
206 IntellectSoft, Advance imaging Algorithms for Digital Twin Reconstruction.

monitored in order to promptly identify the needs for interventions. For instance, the EU-funded COGITO[207] project targets to leverage on near-real-time data from data capture tools to timely detect health and safety hazards for humans, construction quality defects as well as to constantly update the workflow management in order to minimise construction project time/cost overruns and alleviate workplace accidents. Specific to the **maintenance and operations of urban areas**, Digital Twins provide the added value of real-time data.

Although 2D and 3D models (e.g. BIM models) have been used for some time, such models include, at best, statistical data and forecasts based on information gathered in the past. Digital Twin can **complement and update 3D models** with GPS data from public transports, weather data, water levels of the rivers that flow through the city, air pollution on the different streets, or even the amount of people that are in the main shopping street at a certain moment in time[208]. Basically, **urban-level Digital Twins** gather together real-time data from multiple sources and make it available to citizens, as well as policymakers and administrators so as to take informed decisions based on actual data[209].

Figure 43: The Digital Twin concept: Data are captured and streamed to a digital platform, which, in turn, performs real-time analysis to optimise the design and the performance[210]



Source: Sphere (2020).

[207] More information at : https://cogito-project.eu/

[208] OASCities. Three key challenges towards Digital twin adoption at scale. https://oascities.org/three-key-challenges-towards-digital-twin-adoption-at-scale/

[209] Ibidem.

[210] SPHERE Project. https://sphere-project.eu/

Box 2: Examples of Digital Twin in the EU

Digital Twins can be used by the public sector to have a digital and updated stock-tacking of buildings. Digital Twins can also be used to provide open data to citizens and companies, as well as to develop better and more consistent urban projects. They can be used at project level, city level, regional level, national level and, under certain conditions, even up to global level.

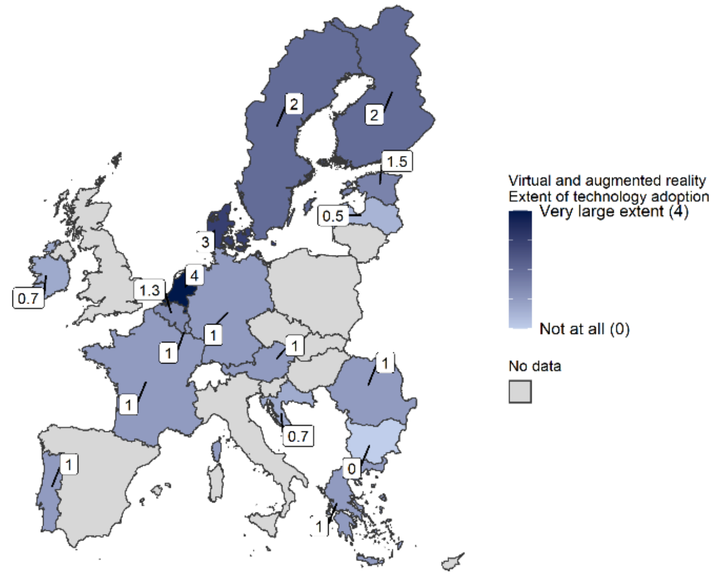
- Project level
  - **Port of Antwerp, Belgium**. Antwerp Port Authority has been working on a digital representation of the port area. The Antwerp Port Information & Control Assistant forms the 'brain' of the application, combined with a 3D interface with real-time information[211].
  - **3D-Printed bridge, the Netherlands.** In Amsterdam, start-up MX3D has developed a 3D-printed bridge. The Imperial College London, the University of Cambridge, and the Newcastle University have developed a Digital Twin of the bridge to analyse the data provided by the sensors, as well as conducting tests of the 3D-printed material[212].
- City level
  - **Helsinki, Finland.** The city of Helsinki has developed a complete 3D map of the city[213]. This map allows not only to view the urban planning, but also the single buildings' data (e.g. number of floors, total surface, etc.).
  - **Herrenberg, Germany.** In cooperation with multiple institutions, the city of Herrenberg has been working on a complete Digital Twin, which will also give the possibility to explore the city in virtual reality[214]. The Herrenberg Digital Twin differs from other simulation-based studies by linking and combining various urban data from models, analysis, and simulation and by the implementation of social data collected from citizens[215].
- Regional level – **Flanders, Belgium**. The Smart Flanders[216] network brings together 13 Flemish cities and the Flanders region as a network with the ambition to create a Flanders Digital Twin as a tool to open and democratise available Smart City data to citizens, companies and service providers and to use the available (government) data for co-creative policymaking[217].
- National level – **Luxembourg / Estonia**. Luxembourg's Institute for Science and Technology[218] and Estonia's Ministry of Economic Affairs and Communications[219] are developing nationwide Digital Twins of their respective countries. Once completed, these will be the world's first Digital Twins covering an entire country.
- Ocean level - **Digital Twin of the Ocean**. The European Commission has launched a tender[220] in 2020 for the development of a Digital Twin of the Ocean by building existing infrastructures and relevant Horizon 2020 and R&D projects (e.g. Copernicus marine environment monitoring service, CMEMS, BlueCloud, EMODNet, portals from ERICs, IMMERSE, ESA Ocean Science Cluster, etc.).
- Global level – **Destination Earth[221]** (DestinE) project is a European project to develop a very high precision digital model of the Earth to monitor and simulate natural and human activity, and to develop and test scenarios that would enable more sustainable development and support European environmental policies.

211 Port of Antwerp. www.portofantwerp.com/en/
212 Industryeurope, World's first 3D printed steel bridge with Digital Twin Tech. https://industryeurope.com/world-s-first-3d-printed-steel-bridge-with-digital-twin-tech/
213 Helsinki, Karttapalvelu. https://kartta.hel.fi/3d/#/
214 Dembski, F. ; Wossner, U.; Letzgus, M.; Ruddat, M.; Yamu, C. (2020). Urban Digital Twins for Smart Cities and Citizens: The Case Study of Herrenberg, Germany. Sustainability 2020 12 2307.
215 Ibidem.
216 Smart Flanders. https://smart.flanders.be/
217 Digital Urban Twins. https://www.digitalurbantwins.com/flanders-twin
218 Geoportail Luxembourg. https://www.geoportail.lu/fr/
219 InvestinEstonia, A full 3D model of Estonia will be created, including buildings, structures located below the ground and even plants. https://investinestonia.com/a-full-3d-model-of-estonia-will-be-created-including-buildings-structures-located-below-the-ground-and-even-plants/
220 European Commission, Transparent & Accessible Seas and Oceans: Towards a Digital Twin of the Ocean. https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/lc-gd-9-3-2020
221 European Commission, Destination Earth (DestinE). https://ec.europa.eu/digital-single-market/en/destination-earth-destine

2.2.3.3 Virtual and augmented reality

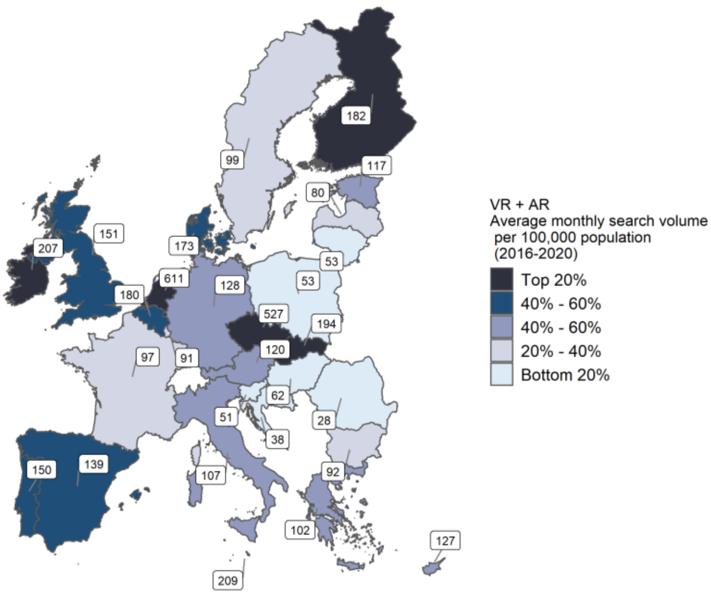
Virtual and Augmented Reality (VR/AR) is a technological innovation that incorporates virtual elements into real surroundings or directly by visualising the whole environment. More specifically, Virtual Reality refers to a completely simulated digital environment, usually with a degree of user interaction possible[222]; whereas Augmented Reality consists of layering digital elements in the real-world environment through computer-generated sensory inputs[223]. **VR/AR in construction makes it possible to combine digital architectural models with the physical reality of a construction site, or to directly visualise the final outcome of a project even before construction works have started**. VR/AR can overlay computer generated graphic elements onto camera-captured videos, so it appears in real time, in the exact location in the real world. In terms of construction projects, AR involves the placement of a 3D model of a prospective design into the existing space[224].

Figure 44: Extent of VR and AR adoption in EU MS[1]



Source: ECSO survey, 2020

Figure 45: Average monthly VR/AR search volume (2016-2020)[1]



Source: Google Ads, 2020

The European VR/AR market is estimated to grow significantly with an annual growth rate of more than 36% in the 2019-2025 period[225]. However, the market adoption in the EU is still limited[226] and, for the moment, only 12% of the construction companies declare using virtual or augmented reality in their activities[227], with larger companies taking the lead in terms of adoption. When it comes to adoption by EU MS, the results from the EIB 2019 Investment Survey[228] confirm what is shown in Figure 44. Virtual and Augmented reality have very low adoption levels across the EU, although Italy, Spain and Poland and a few

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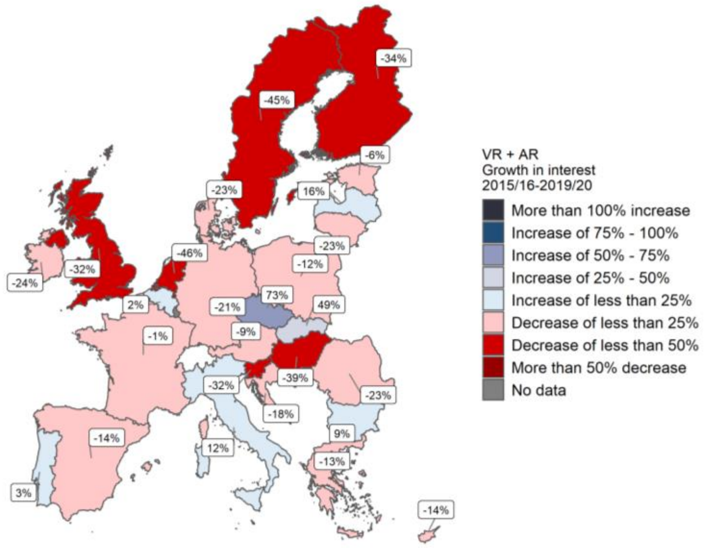
[222] DesignBuildings, Virtual reality in construction. https://www.designingbuildings.co.uk/wiki/Virtual_reality_in_construction
[223] RedShift, What is Augmented Reality. https://redshift.autodesk.com/what-is-augmented-reality/
[224] ESub Construction Software, 7 uses in 2020 for Augmented reality in Construction. https://esub.com/blog/7-uses-in-2020-for-augmented-reality-in-construction/
[225] AP, Insights into the Augmented Reality Industry in Europe to 2025 - Motivators, Restraints and Opportunities. https://apnews.com/press-release/business-wire/8562f2afc0ad4a4dad7815cd0fd8b42b
[226] Information based on the survey. ECSO survey results are not statistically representative and should be interpreted accordingly.
[227] European Investment Bank Investment Survey (EIBIS) 2019. https://www.eib.org/en/publications/econ-eibis-2019-eu
[228] Ibidem.

other MS did not respond to this part of the survey. This is considered evidence of the low awareness on this technology in the sector.

Figure 46: VR/AR's growth in interest (2015-2020) [229]



Source: Google Trends, 2020

The state of play of VR/AR is also confirmed by the analysis of Google trends data. During the reference period 2016-2020, online searches on VR and AR have been modest in comparison to other technologies. Germany and the Netherlands have been the countries with the highest concentration of overall search volume. When it comes to growth in interest, i.e. increase in online searches, Czech Republic, Slovakia, Luxembourg, and Latvia have registered the largest increases, whereas Sweden and the Netherlands had a decreasing trend (see Figures 45 and 46).

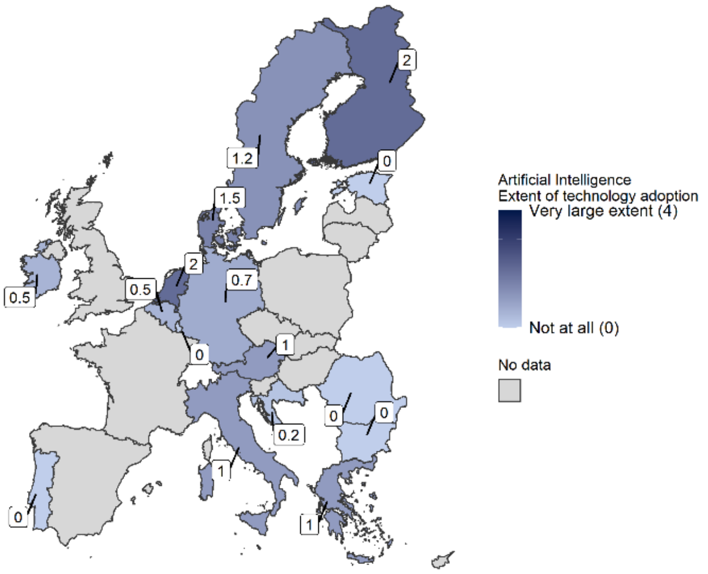
In the construction sector, VR/AR can be used to simulate real world situations and scenarios, and, consequently, it has a wide range of applications in several phases of a building lifecycle, in particular in the design, planning, construction, and management phases[230]. They can be used to visualise complex projects, and to provide a simulated environment in which engineers, project managers and clients can experience and work on the digitally constructed virtual model, thus having a realistic visualisation of the final result, its characteristics and functionalities.

Project ideas can therefore be virtually and realistically visualised long before the construction process begins, hence resulting in being a valuable tool for business development as well[231]. This has clear advantages in detecting possible design issues and providing automatic measurements, and hence enhances communication between designers, architects, engineers, clients, and stakeholders across all phases of the buildings' lifecycle. This allows for virtual on-site reviews, which prevents additional costs and delays[232]. Furthermore, VR/AR can be used to give workers hands-on experience and training prior to entering a construction site[233]. For instance, the EU-funded CSETIR[234] (acronym for Construction Safety with Education and Training using Immersive Reality) project plans to use VR/AR to simulate construction scenarios to train teachers, technicians and engineers on the identification and prevention of risks. Furthermore, VR/AR is increasingly used in real estate for marketing and sales purposes, allowing buyers to visit the building before its realisation[235].

229 The map is based on the analysis of Google research data. Countries coloured in grey are those for which no data was available.
230 European Commission, JRC Science for Policy Report.
231 Ibidem.
232 ESub Construction Software, 7 use in 2020 for Augmented Reality in Construction.
233 KHL, VR and AR: Visualising the future of construction. khl.com/construction-europe/vr-and-ar-visualising-the-future-of-construction/138994
234 CSETIR. http://csetir.civil.auth.gr/
235 Information retrieved from interviews.

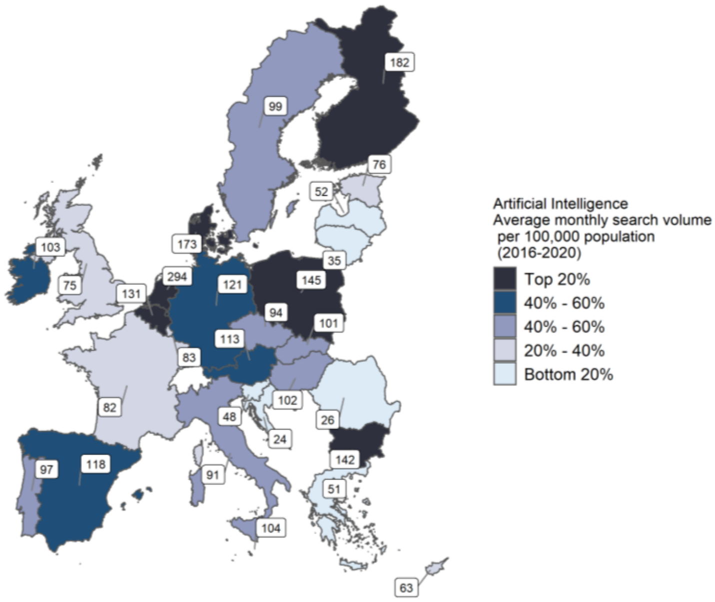
2.2.3.4 Artificial intelligence

Figure 47: Extent of AI adoption in EU MS



Source: Google trends, 2020

Figure 48: Average monthly AI search volume (2016-2020)[237]



Source: Google Ads, 2020

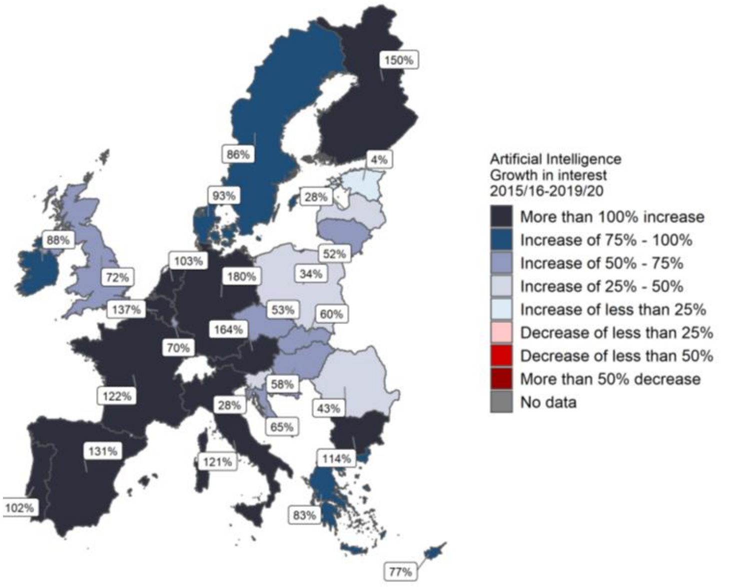
Artificial intelligence (AI) is a disruptive technology consisting of a machine that through Artificial Neural Networks, i.e. a computing system programmed to emulate the way the human brain processes information and mimics human functions, like problem-solving, pattern recognition, and learning[236].

AI has recently acquired ground-breaking capabilities thanks to important progresses made in computational power, whose impact can stretch through the whole lifecycle of a building or infrastructure[238]. Nonetheless, as can be seen in the Figures below[239], online interest in AI has been growing significantly in the 2015-2020 period, with a relative concentration in Central and Northern Europe, with Germany, Austria, and Finland leading the way. Although more moderate, interest in AI is strong also in the other MS, showing that, even if with different paces, AI has been rapidly gaining attention in the EU market.

In the construction sector, the adoption of AI is still very limited and mainly confined to pilot projects[240], with tests being made in structural analysis, design, and optimisation. Although no official statistical data on its market adoption is available at the moment of the writing, the responses from the survey carried out could be used to depict the adoption of AI across the EU. As Figure 47 shows, most MS reported a very low, if any, adoption rate, with the notable exception of the Netherlands, Finland and Denmark. Furthermore, many respondents from different MS were not able to provide an answer on the adoption rate of AI in their countries, to further underline the low visibility this technology has in the construction sector.

236 Constructible, The benefits of AI in Construction. https://constructible.trimble.com/construction-industry/the-benefits-of-ai-in-construction
237 The map is based on the analysis of Google research data. Countries coloured in grey are those for which no data was available.
238 European Commission, PRC Science for Policy Report.
239 The map is based on survey results. 38 participants responded to this question. Countries coloured in grey are those for which no data was available. ECSO survey results are not statistically representative and should be interpreted accordingly.
240 Information retrieved from interviews.

Figure 49: AI's growth in interest (2015-2020)[241]



Source: Google Trends, 2020

In the design phase, AI can support architects and planners with generative design approaches, meaning that AI integrated with BIM software is able to explore all the possible variations of a design[242], given the constraints and boundary conditions from which designers and engineers can choose from. Machine learning has recently started to be used to identify potential errors and incompatibilities linked to variations in the design[243]. In fact, software has been developed to perform, following modifications to the original parameters, massive automatic checks of the conformity of all kinds of computable rules and interferences, including mechanical, electrical, and plumbing plans, without direct human control, thus significantly reducing the time required by public administrations to approve construction projects.

The American company ALICE Technologies[244] has developed an AI-powered construction simulation platform able to analyse a project's requirements and generate efficient construction schedules. According to the information reported on their website, the use of AI in the design phase can lead to 32% reduction in construction costs and 10.2% faster construction schedules[245]. During the construction phase, construction companies and building material manufacturers and distributors[246] can use Artificial Neural Networks to, for example, **predict cost overruns** based on factors such as the project size, the type of contract and the competence level of project managers[247]. Historical data such as planned start and end dates are used by the project manager to feed into predictive models to envision realistic timelines for future projects[248].

Moreover, the implementation of Artificial Neural Networks can be used for **structural damage assessment** (e.g. detecting structural damage from the earthquake) or structural health monitoring (e.g. identification of damage and nonlinearities in wind turbine blades based on a pattern recognition technique)[249]. When it comes to construction and demolition waste, AI can be used to **predict waste generation[250]** and, if combined with appropriate sensors (e.g. infrared), automatically sort construction waste[251]. The first real-life

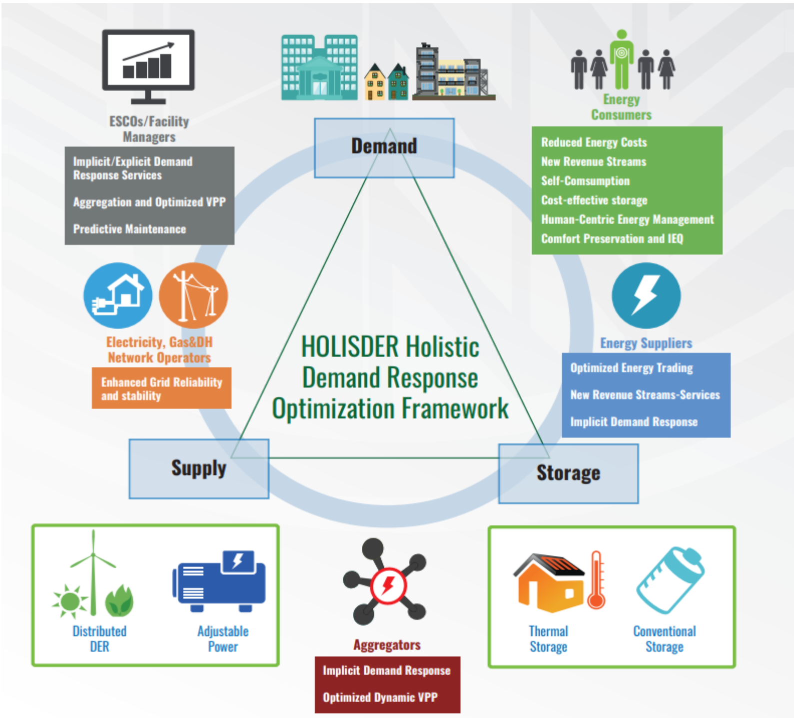
241 The map is based on the analysis of Google research data. Countries coloured in grey are those for which no data was available.
242 Information gathered from interviews.
243 Constructible, The Benefits of AI in Construction.
244 ALICE Technologies. https://www.alicetechnologies.com/home
245 ALICE Technologies. Case studies. https://blog.alicetechnologies.com/case-studies
246 RolandBerger. Artificial Intelligence in the Construction Industry. https://www.rolandberger.com/en/Insights/Publications/Artificial-intelligence-in-the-construction-industry.html
247 Information gathered from the interviews.
248 Constructible, The Benefits of AI in Construction. https://constructible.trimble.com/construction-industry/the-benefits-of-ai-in-construction
249 European Commission, JRC Science for Policy Report.
250 Cha, G-W.; Moon, H. J.; Kim, Y.M.; Hong, W.H.; Hwang, J.H.; Park, W.J.; Kim, Y.C.. Development of a Prediction Model for Demolition Waste Generation Using a Random Forest Algorithm Based on Small DataSet. International Journal of Environmental Research and Public Health.
251 Inno4SD, Advanced Sorting Techniques for Construction and Demolition Waste. https://www.inno4sd.net/advanced-sorting-techniques-for-construction-and-demolition-waste-278

applications of AI in the construction sector demonstrated a potential for up to 40% increase in labour productivity and project completion saving more than 10% of the budget[252].

Such AI-based methods are becoming more and more popular particularly due to their capacity to recognise patterns and classify problems. These methods, the more they are used the more precise and reliable they become as they have an increasingly-growing basin of data to use (machine learning). Indeed, the widespread deployment of structural monitoring systems (such as IoT) will also provide the essential big data to train machine learning algorithms and to develop more accurate and effective AI-based systems[253]. Construction projects at all phases will become a source of useful data for similar future projects, in order for AI systems to leverage on existing information and continuously improve the outcomes and provide a growing level of precision and reliability[254]. AI can also be **combined with IoT sensors** to suggest the optimal time to take a specific action (e.g. to clean a filter) before a potential problem arises but no earlier than necessary, so as to save money. It can also automatically order replacement parts to make sure that these parts are available when needed and avoid unproductive waiting time[255].

AI can as well be used by facility managers, construction companies and building owners for predictive maintenance and optimal energy management[256]: Sensors allow the constant monitoring of environmental parameters and detect the presence of people in the buildings managed. AI-based tools then adjust the heating and electricity consumption not only on the basis of real time data but by analysing the building's usage statistics to adapt and anticipate needs[257]. For instance, the Horizon 2020 project "Holisder" developed an AI demand response system to manage energy utilisation in a building. Holisder connects different technologies in a single framework to proactively and intelligently enhance the building's energy management system with the integration of ICT-enabled human-centric optimisation and predictive maintenance functions[258] (see Figure 50).

Figure 50: Holisder[1] will enable energy costs reduction by integrating Real-Intelligence in Energy Management Systems enabling Demand Response Optimisation in Buildings and Districts



Source: Holister (2020).

[252] RolandBerger. Artificial Intelligence in the Construction Industry.
[253] Inno4SD, Advanced Sorting Techniques for Construction and Demolition Waste.
[254] Constructible, The Benefits of AI in Construction.
[255] RolandBerger. Artificial Intelligence in the Construction Industry.
[256] Constructible, The Benefits of AI in Construction.
[257] European Commission, JRC Science for Policy Report.
[258] Holister, Holistic Demand Response Optimization Framework. http://holisder.eu/

2.3 Summary of the main findings

This chapter presented an overview on the state of play of the construction digital technologies in the EU.

Data acquisition technologies, namely sensors, IoT, and 3D scanning, are the starting point for the digitalisation of the construction sector, as they provide most of the data necessary to build and develop the digital construction ecosystem. In this field, sensors are the technology with the highest level of market maturity and technological readiness; however, significant margins of improvement are present when it comes to their integration on existing buildings. The growth in their adoption will allow for economies of scale to take effect and, consequently, increase their affordability and speed-up their diffusion.

Automating processes in the construction sector refer to the use of robots, 3D printing (additive manufacturing), and drone to automate specific tasks in the construction sector. The benefits they can bring consist of increased efficiency, greater precision, and improved workplace safety and security. However, these technologies are still at different stages of development.

Robotics and 3D printing are still at the development phase and still not widely adopted by companies in the sector, if not for very specific and limited tasks or in projects specifically thought for their use. At the same time, drones are being increasingly used, thanks to the development and improvement of the sensors that they are equipped with.

The effective use of digital data from construction represents a key part of the digitalisation of the construction sector. In fact, **data analysis** is needed to give a meaning to all the data gathered and deliver tangible improvements and benefits. However, as the technologies and innovations in this category are deeply connected to the maturity of the technologies mentioned in the Data acquisition and Automatic processes parts, their status varies significantly from one to the other.

BIM is more and more utilised in the construction sector, thanks to the important benefits it brings it terms of cost-saving, better cooperation among stakeholders and, more generally, improved project performance. However, it is still too limited to the design phase of big projects. Its diffusion to smaller projects and to the maintenance phase of buildings is the next challenge. Virtual and augmented reality and Artificial Intelligence are still not widely adopted in the construction sector. However, the interviews conducted as well as the analysis of the survey replies showed that there is a growing interest in such technologies and a rapid development is expected over the next years. Finally, Digital Twins are for the moment limited to few pilot projects, but the majority of public and private stakeholders interviewed agrees that they are the logical destination for the development of the sector, as they aggregate many of the other technologies.

3. Digitalisation policies and initiatives in the EU

Governments play a key role in supporting the digitalisation of the construction sector, through the implementation of policies and instruments meant to incentivise the uptake of digital technologies, practices and business models. Indeed, it is important to underline that, to be fully effective, digitalisation needs to be embraced by all actors involved in the construction value chain, both private and public. This report will hence look at how the public sector has supported digital technologies in the construction sector.

The objective of this section is to provide an overview of how the EU and its Member States approach and support digitalisation of the construction sector. It notably shows that governments have at their disposal several instruments and policies, themselves supported by other policies/platforms and financial instruments, which can be tailored to the national and sectoral context – depending on the objective sought.

After a short overview of the EU policy initiatives and framework put in place in relation to supporting the digitalisation of the EU construction sector, this section will analyse five type of policy initiatives:

1. **Digitalisation policies related to the construction sector**, which often put in place a broad framework aiming to support the adoption of digital technologies – sometimes through different policy areas.
2. **Construction-related digital platforms**[259], which are often used to support the coordination between public and private sector initiatives and to facilitate policy implementation. This section will provide an overview of some of the main platforms in the different Member States.
3. **Public procurement policies** with a specific focus on those policies or requirements that contribute to fostering digitalisation in the construction sector – such as BIM requirements in public tenders.
4. Government e-services also play a key role in facilitating the digitalisation of construction related processes. This is for instance the case of the **digitalisation of building permit systems**.
5. **Digital building logbooks**, which are common repositories for all relevant building data, are also another way through which government can support the digitalisation of the construction sector.

These five types of initiatives constitute the panorama of policies developed by policymakers to incentivise the use of digital technologies in the construction sector.

3.1 EU policy framework

Digital technologies open new horizons for the industry to become more innovative, efficient, and sustainable. Recent studies estimate that digitalisation of products and services can add more than EUR 110 billion of annual revenue to the European economy in the next five years[260]. To transform this potential into reality, the European Commission has developed in the past few years a policy framework geared towards the digital transformation of the EU economy, including in the construction sector. To analyse this framework, this section groups EU initiatives in three categories: i) policies relating to the financing of

[259] As introduced in the glossary, digital construction platforms are virtual or physical platforms gathering private and public stakeholders, aiming to support the integration of digital technologies in the construction sector. These can also take the shape of "associations". National digital platform related to construction play a role in helping implementing construction policies by e.g. coordinating the digitalisation of public and private stakeholders' initiatives, providing a dialogue space.

[260] https://ec.europa.eu/digital-single-market/en/digitising-european-industry

digitalisation; ii) those supporting the regulatory framework around digitalisation; and iii) broader initiatives or strategies supporting the coordination of action between EU Member States. 3.1.1 Strategies

Construction Competitiveness

Construction 2020[261,262] is a Strategy for the sustainable competitiveness of the construction sector its enterprises (2012). It is completed by the Construction 2020 Action Plan, to support the construction sector in its adaptation to key upcoming challenges and to promote the sustainable competitiveness of the sector. Its first thematic objective concerns Innovation, aiming at boosting the digital uptake in the construction sector.

Energy efficiency and renovation of buildings

The Renovation Wave[263] is a strategy aiming to foster building renovation to address climate change and support the recovery and the green and digital transition. More specifically, the EC aims to at least double renovation rates in the next ten years, thereby i) reducing energy poverty in the EU; ii) improving the quality of life for people living in and using the buildings; and iii) reducing Europe's greenhouse gas emissions – taking into account that the building stock in the EU account for 40% of energy consumed and 33% of CO_2 emissions. This will, among other objectives, foster digitalisation, improve the reuse and recycling of materials, and contribute to creating employment and growth opportunities across the renovation supply chain.

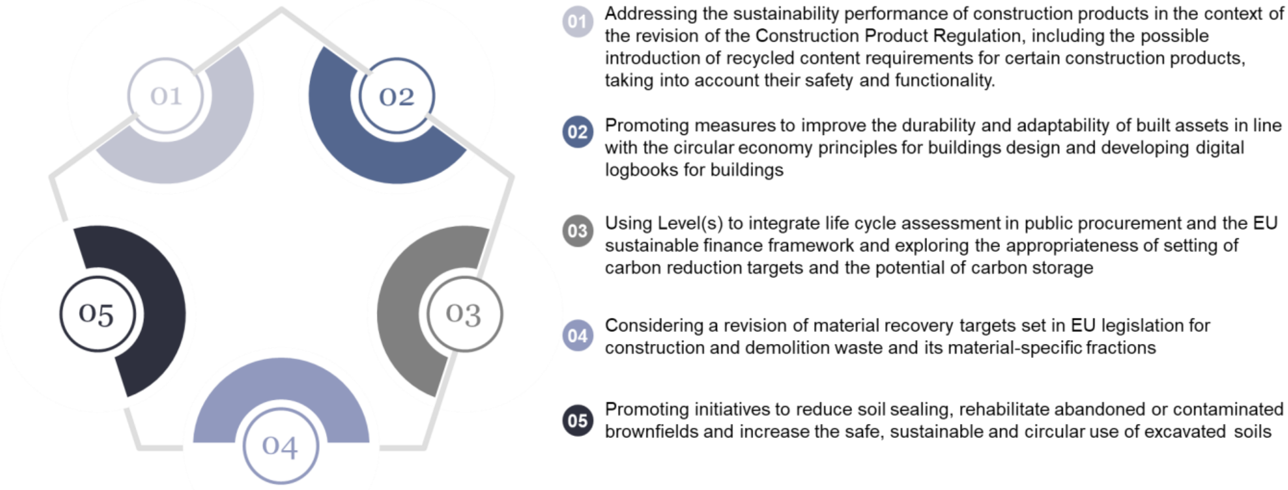
The Renovation Wave builds on and complements other policy areas, such as the EU Clean Energy for all Europeans package, and most importantly the Directive on the Energy Performance of Buildings (2010/31/EU) – amended in 2018 (2018/844/EU). The latter Directive promotes the use of digital technologies but also energy performance certificates (EPC), which must be issued when buildings are sold or rented thereby contributing to data sharing[264]. In fact, the Renovation Wave goes one step further when it comes to digitalisation, with the EC i) introducing digital building logbooks, which will integrate all building related data provided by the upcoming Building Renovation Passports, Smart Readiness Indicators, Level(s) and EPCs thus making sure that the data collected is compatible, collected and used throughout the renovation journey of buildings; ii) supporting the investments and uptake of digital technologies in the construction sector by building synergies with Digital Innovation Hubs and Testing and Experimentation Facilities and Horizon Europe,; and iii) supporting BIM by promoting this digital technology in public procurement for construction (including a methodology for public authorities to conduct cost-benefit analysis for the use of BIM)[265]. Last, as announced in the strategy, the EC is also expected to develop a unified EU Framework for digital building permits and establish a trusted scheme for certifying energy efficiency meters in buildings that can measure actual energy performance improvements.

Circular economy and waste

Of particular importance is the EU Circular Economy Action Plan, which promotes circularity principles throughout the lifecycle of buildings and construction, as described in the figure below.

261 https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupMeetingDoc&docid=35639
262 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52012DC0433&from=EN
263 https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1835
264 European Commission (2020). A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1603122220757&uri=CELEX:52020DC0662
265 Digital industrial platforms allow stakeholders to collect and make better use of this data.

Figure 51: EU Circular Economy Action Plan activities relating to the lifecycle of building and construction



Adapted from: EC (2020).

In addition to the Circular Economy Action Plan, the Waste Framework Directive (Directive 2008/98/EC on waste) set up as an objective to recycle 70% of Construction and Demolition Waste (CDW). The latter is the largest stream of waste - accounting for a third (374 million tonnes) of the total waste generated in the EU[266]. This was later completed by non-binding measures such as the EU Construction & Demolition Waste Management Protocol (2016) or the EU Guidelines for audits before demolition of building (2018), which intend to support and guide the efforts of member states in the area of CDW.

Digitalisation

Digitalisation policies provide both financial and non-financial support for the uptake of digital technologies in the economy, including in the construction sector. In doing, so, they can also contribute to other policy areas, including energy efficiency and the circular economy – as recognised in the Renovation Wave. The EC supports directly or indirectly the digitalisation of the construction sector through several policies and programmes, including: the Construction 2020 Strategy, the Renovation Wave, but also broader policies such as the EC Communication on Shaping Europe's digital future, which includes inter alia an EU Digital Strategy and a White Paper on Artificial Intelligence (AI). These strategies are supported by the Digital Innovation Hubs (DIHs) and Testing and Experimentation Facilities

Figure 52: Digital Innovation Hubs services[267]

Source: Adapted from EC (2020).

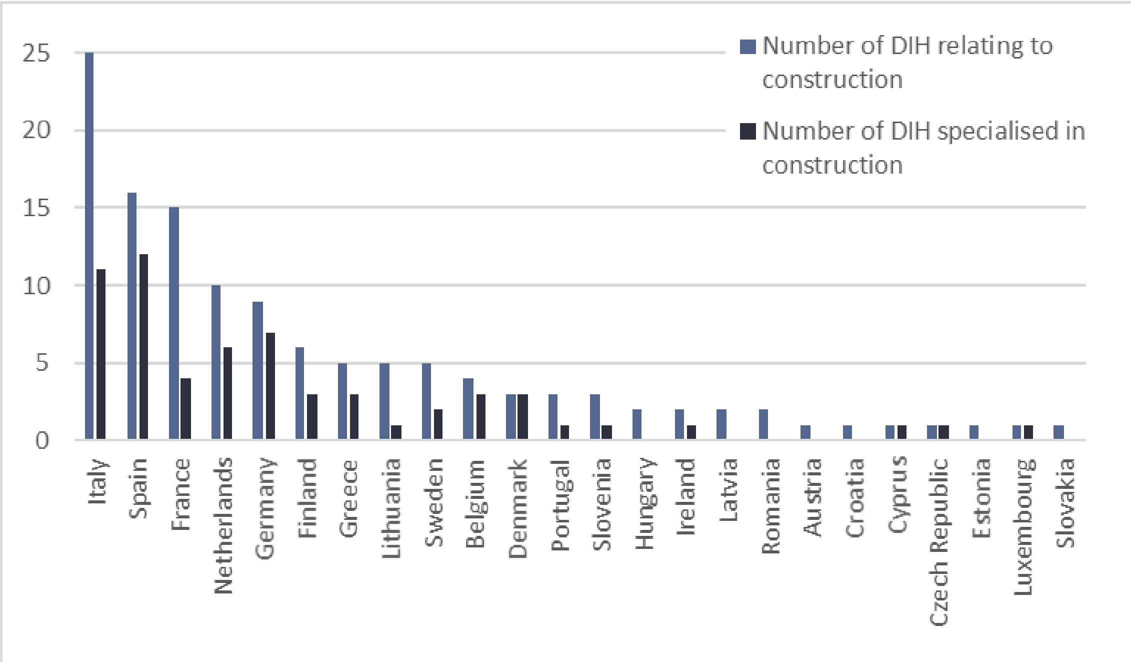
[266] European Commission (2016). EU Construction & Demolition Waste Management Protocol. https://ec.europa.eu/docsroom/documents/20509/attachments/1/translations/en/renditions/native

[267] EC (2020). Digital Innovation Hubs in Europe. https://ec.europa.eu/digital-single-market/en/digital-innovation-hubs

In particular, the DIHs play a key role in supporting companies, whether small or large, high-tech or not, to take advantage of digital opportunities. Companies that want to go digital have the choice between a wide range of digital technologies and software, and may need support in identifying the best solution to their needs. In addition, the challenges start once the technologies are acquired – meaning that businesses need to invest human and financial resources to familiarise themselves with the technology, adapt their routines accordingly, train staff etc. The DIHs tackle such a gap by providing a range of services that could be assimilated to "technical assistance", as described in the figure above. Moving forward, the DIHs are expected to play a key role in supporting the uptake of e.g. digital technologies, including in the construction sector (in particular SMEs and midcaps).

About 124 fully operational DIHs offer services that can be relevant for the construction sector, while 69 DIHs specifically focus on supporting the digital transformation of the construction sector[268]. These are spread over 23 Member States, with countries such as France, the Netherlands, Spain, and Italy having more than 10 DIH related to the construction sector, including over 50% in average specialised in the construction sector (see more information in the graph below). They seem to be focusing mostly on the five following technical competencies (or digital technologies): Internet of Things (e.g. connected devices, sensors and actuators networks), data mining, big data, database management; artificial Intelligence and cognitive systems; robotics and autonomous systems and simulation and modelling[269]. In terms of services provided, they mostly focus on ecosystem building and networking, collaborative research and education and skills development, awareness creation and concept validation and prototyping.

Figure 53: Number of construction DIH per EU Member States



Source: JRC (2020), Digital Innovation Hubs and Digital Innovation Hubs contribution to digital transformation in Construction sector[270].

[268] JRC (2020).Digital Innovation Hubs. Link

[269] EC (2020). Digital Innovation Hubs contribution to digital transformation in Construction sector. https://s3platform.jrc.ec.europa.eu/documents/20182/318091/DIHs+for+Construction+policy+area.pdf/ae000c04-3a45-4656-9eb6-463e7a5a7f92

[270] Ssee more information at https://s3platform.jrc.ec.europa.eu/documents/20182/318091/DIHs+for+Construction+policy+area.pdf/ae000c04-3a45-4656-9eb6-463e7a5a7f92

Complementing the DIHs, the EC will launch large-scale reference Testing and Experimentation Facilities (TEF) for AI hardware, software, systems and solutions, and underlying resources (data, computing, cloud) in several sectors. In particular, TEFs aim to foster the deployment of AI in reference sites for applications in essential sectors such as manufacturing, smart cities and smart mobility (including environment and climate perspective)[271]. Both DIHs and TEFs can accompany the digitalisation of the construction sector by facilitating the stages of technology development and adoption, which are of prime importance – especially for companies with limited expertise and financial resources.

Skills development and research and innovation

To address the issue of digital skills shortages, the EC has developed several policy initiatives, as described in the box below. These may help address the skill mismatch on the long-term.

Box 3: EU policies for workforce qualification

The European Commission has recognised the importance of education and continuous learning, as well as the detrimental effects that a shortage of qualified workforce has on the European economy, construction sector included. For this reason, the Commission launched a number of initiatives aimed at addressing the issue:

Construction Blueprint[272]

Skills Blueprint for the Construction Industry is an EU funded project aiming to put in place a new strategic approach to sectoral cooperation on skills, and addressing the skills' mismatch between companies' needs and training centre offer. This project is notably expected to develop appropriate curricula and a mapping tool (Observatory) to provide valuable information about particular skill needs at least at regional/national level.

European Skills Agenda[273]

A 5-year Plan to help individuals and businesses to develop more and better skills and put them to use in a context growingly characterised by the climate and digital transformations. The purposes of this plan are to strengthen EU's sustainable competitiveness, ensure social fairness, and build resilience in the economy.

European Pact for Skills[274]

A shared engagement model for skills development in the EU officially launched on 10 November 2020. It is part of the European Skills Agenda and it is meant to support upskilling and reskilling of workforce to help deliver on the ambitions of the green and digital transitions and of the EU Industrial and SME Strategies.

BUILD UP Skills initiative[275]

BUILD UP Skills is a strategic initiative which started under the Intelligent Energy Europe programme to boost continuing or further education and training of craftsmen and other on-site construction workers and systems installers in the building sector. Its final aim is to increase the number of qualified workers across Europe to deliver building renovations, which offer high-energy performance as well as new, nearly zero-energy buildings. The initiative addresses skills in relation to energy efficiency, digitalisation and renewable energy systems and measures in buildings.

Complementing skills development initiatives, the EC has also been active through its upcoming programmes, in promoting research and innovation in the construction sector – which will support its digital transformation. In particular, Horizon Europe (2021-2027) is expected to play a key role in this regard, through its **Cluster 4: "Digital, Industry and Space"[276]**, which is part of its most prominent pillar 2 "Global

[271] EC (2020). Workshops on reference testing and experimentation facilities for Artificial Intelligence in the Digital Europe Programme. https://ec.europa.eu/digital-single-market/en/news/workshops-reference-testing-and-experimentation-facilities-artificial-intelligence-digital

[272] See more information at: Construction Blueprint. https://constructionblueprint.eu/context/

[273] European Commission, European Skill Agenda. https://ec.europa.eu/social/main.jsp?catId=1223&langId=en

[274] European Commission, Pact for Skills. https://ec.europa.eu/social/main.jsp?catId=1517&langId=en

[275] BUILD UP Skills. http://www.buildup.eu/en

[276] At the time of writing of this report, more details on Cluster IV were not available. However the EC is expected to publish further information on the Cluster, namely the specific topics it will be targeted by the end of Q1 2021.

Challenges and European Industrial Competitiveness“[277]. One of the priorities of the key research and innovation orientation aims to enable “*a “new way to build”, for construction with lower environmental footprint, through modularisation, digital technologies, circularity and advanced materials, as well as standards and safety*”[278]. Put in practice, this will translate is expected to translate in a higher productivity and competitiveness, a higher degree of digitalisation, automation and decarbonisation, and the minimisation of labour accidents. It does so by supporting the introduction of disruptive technologies in the construction site and demonstrate their impact on the sector (primarily on new construction)[279]. While the cluster does not target specific digital technologies, Horizon Europe is expected to contribute to bring digital technologies closer to market readiness and feed the innovation cycle with discoveries that may lead to disruptive solutions[280].

A new approach to partnerships has been developed as part of Horizon Europe, the so-called European Partnerships[281]. As part of these figures the Built4People partnership, which was co-programmed, i.e. developed by the EC in collaboration with other public and private stakeholders and hence integrating their needs and interests. During the 2021-2027 period, it will support innovation targeting the ‘people-centric sustainable built environment’ by fostering collaboration between public and private sector actors on research[282]. This initiative looks at the sustainable built environment holistically, expected to contribute to the seven following impact areas: i) decarbonisation, clean energy and mobility; ii) resource efficiency and circularity; iii) water & biodiversity; iv) resilience; v) value and cost; vi) health and wellbeing; and vii) just transition[283]. As part of the partnerships, innovation clusters bringing together the academia, public and private sector, are expected to be set up in most EU Member States, with a view to introduce innovation throughout the construction value chain.

With a budget of EUR 95.5 billion[284], Horizon Europe will be implemented though grants but also financial instruments. In fact, the latter aims to stimulate more investment in research and innovation, notably by the private sector; and leverages and complements national/regional initiatives. In this context, EUR 3.5 billion of the total budget will be implemented through InvestEU under its RDI Window and the SME Window[285]. Horizon Europe is expected to facilitate the development of construction related digital technologies, helping them reach a stage of industrialisation – i.e. a stage where technology costs are relatively low thanks to economy of scale, and the technologies technical and business case is proven.

3.1.2 Funding

Financing schemes often accompany the adoption of policies, with a view to foster their implementation on the ground. This section will hence analyse those relevant to digitalisation in the construction sector, moving forward in the next programming period 2021-2027. In doing so, we will focus on the Cohesion

277 See more information at: https://ec.europa.eu/info/horizon-europe_en

278 EC (2020 :74). Orientations towards the first Strategic Plan implementing the research and innovation framework programme Horizon Europe. https://ec.europa.eu/research/pdf/horizon-europe/ec_rtd_orientations-towards-the-strategic-planning.pdf

279 EC (2020). Keynote: Horizon Europe and the Green Deal. https://www.bayfor.org/fileadmin/user_upload/BayFOR-pdfs/aktuelles/veranstaltungen/2020-07-15_Building_the_future_2020/BayFOR-building-the-future-2020-02-eleftherios-bourdakis-ec.pdf

280 EC (2020). Orientations towards the first Strategic Plan implementing the research and innovation framework programme Horizon Europe. https://ec.europa.eu/research/pdf/horizon-europe/ec_rtd_orientations-towards-the-strategic-planning.pdf

281 See more information at: https://h2020camera.eu/wp-content/uploads/2020/07/TRA2020_CSAs_22June2020_A_Gentili.pdf

282 See more information at: https://ec.europa.eu/info/events/sustainable-built-environment-research-and-innovation-partnership-under-horizon-europe-2019-dec-12_en

283 EC (2020). Horizon Europe and European Partnerships. https://h2020camera.eu/wp-content/uploads/2020/07/TRA2020_CSAs_22June2020_A_Gentili.pdf

284 See more information at: https://ec.europa.eu/commission/presscorner/detail/en/IP_20_2345

285 EC (2019). Horizon Europe. https://ec.europa.eu/info/sites/info/files/research_and_innovation/strategy_on_research_and_innovation/presentations/horizon_europe_en_investing_to_shape_our_future.pdf

Policy, InvestEU, the Digital Europe programmes, and the Recovery and Resilience Facility. Buildings Performance Institute Europe (BPIE) estimates that each investment of around EUR 1 million in the energy-efficient renovation of a building would create up to 18 short- and long-term jobs.

Cohesion Policy

EU Cohesion Policy will remain one of the key financing sources for digitalisation in Europe, notably through its two first policy objectives: a smarter Europe (innovative & smart economic transformation), and a greener, low-carbon Europe (including the circular economy). The total budget allocated for the 2021-2027 period stands above EUR 330 billion, and 65% to 80% of this will be dedicated to the objectives afore mentioned[286]. In particular, such investments aim to support private and public entities, to digitalise their products and services, and help develop digital connectivity, by investing in ICT infrastructures. While not specifically targeting the construction sector, the Cohesion Policy may be used by managing authorities at the regional/municipal level to e.g. digitalise their public services such as their building permit system, or fund programmes aiming to support the digitalisation of construction companies etc. In addition, it can be expected that the Cohesion Policy will provide business opportunities (e.g. construction of new sustainable buildings) to the construction companies. The profits deriving from such opportunities can then be used to foster their digital transformation.

Digital Europe

Additionally, the Digital Europe programme intends to support the digitalisation of the European economy by supporting investments in AI (EUR 2.2 billion), cybersecurity (EUR 1.8 billion), advanced digital skills (EUR 600 million), and in the use of digital technologies across the economy and society (EUR 1.2 billion). In turn, the construction sector could benefit from some of these investments, whether as a direct recipient but also indirectly (i.e. investment allowing e.g. AI to gain in maturity may facilitate its spread in the construction sector).

Box 4: Draft work programmes of Digital Europe for 2021-2022 relevant to the construction sector

1. Enhancing cybersecurity by deploying a pan-European quantum communication infrastructure and supporting the set-up of a certification scheme for cybersecurity products;
2. Addressing the shortages of digital experts in the EU through dedicated Master's programmes for artificial intelligence, advanced computing and cybersecurity;
3. Providing SMEs and public administrations access to the latest digital technologies by setting up a network of Digital Innovation Hubs;
4. Ensuring a successful digital transformation of health and care services with the EU-wide deployment of innovative and cost-effective data-driven tools and services based on technologies like AI and data analytics;
5. Making ICT products and services sustainable, by prioritising their energy efficiency as well as climate neutrality, reparability, lifespan and recycling;
6. Deploying open, interoperable, trustworthy urban digital platforms tailored to communities' needs, offering easy standardised access to new datasets, and the large scale roll-out of AI-driven services in Smart Energy, Smart Mobility, waste and secondary resource management, industry and (re)manufacturing, healthcare and e-government.

Source: EC, 2020[287].

The scope is hence slightly broader than Horizon Europe, as it touches upon the overall digitalisation eco-system. Thus, while this programme may not have a specific focus on the construction sector, it is expected to impact positively the sector by supporting the shift towards digital upskilling, upgrade of digital infrastructure, and the adoption of digital technologies by companies (through its support to DIHs).

286 See more information at: https://www.eyes-on-europe.eu/cohesion-policy-and-esi-funds-in-2021-2027-a-policy-debate-cohesion-policy-and-esi-funds-in-2021-2027-a-policy-debate/

287 European Commission (2020). Digital Europe. Draft Orientations for the preparation of the work programme(s) 2021-2022. http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=61102

Recovery and Resilience Facility

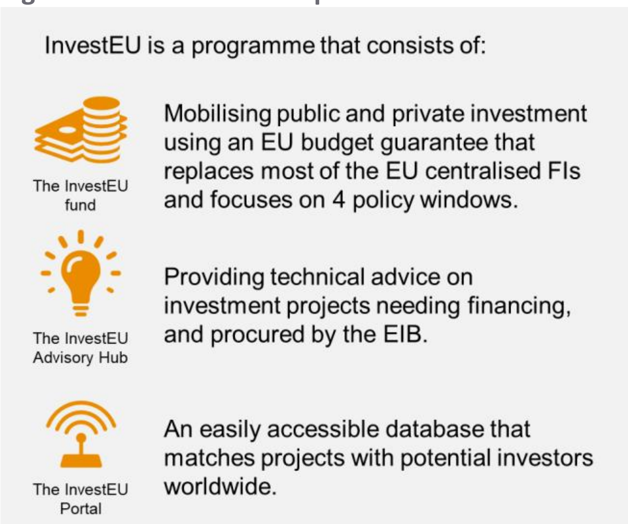
Last, the Recovery and Resilience Facility, with an overall budget of EUR 672.5 billion will play a key role in supporting the digital transformation of EU Member States. In fact, the Commission has proposed that each recovery and resilience plan from Member States include at least 20% of the total budget to digitalisation. It is hence expected that countries shall consider the construction sector and the orientations set through the recent Renovation Wave on their National Recovery Plans.

Invest EU

InvestEU will support companies, thus ensuring a strong focus among private investors on the Union's medium- and long-term policy priorities, in particular the European Green Deal and digitalisation. Based on a budget of EUR 31.6 billion, it is expected to attract about EUR 650 billion in additional investment targeting in part SMEs, and Research, Innovation and Digitalisation.

Like its predecessor, European Fund for Strategic Investments (EFSI), Invest EU relies on three main pillars as seen in the Figure below. This approach may help support construction companies, as it goes beyond financial support, to integrate technical assistance to help make digital projects viable.

Figure 54: InvestEU three pillars



3.1.3 Regulations

While the policy and financing framework are providing support to the digitalisation of the construction sector, regulations and standards can represent effective means to push construction companies to digitalise – thus adopting a "push and pull" type of approach. This sub-section will showcase some of the main regulations and standards that can drive the construction sector to do more in terms of digitalisation.

Public procurement

The EC supports the adoption of digital technologies and particularly BIM in the construction sector, through the EU Directive on Public Procurement (Directive 2014/24/EU). The latter, as it will be detailed in the section below, aims to incentivise EU Member States to take account of digitalisation as a possible requirement in their public procurement process – thus encouraging construction companies to digitalise[288].

[288] It is important to note that implementintg such a criteria in public procurement may also have downsides, such as excluding enterprises, which lack financial means and capacity resources to invest and implement digital technologies such as BIM.

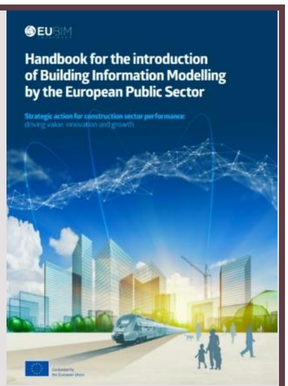
While this is a non-mandatory requirement, 7 EU Member States[289] have since implemented BIM requirements in their national legislation – showing that supporting digitalisation can be done through various angles[290]. To support this process, the EC is expected to provide a recommendation to promote BIM in public procurement, by offering a methodology for public clients to conduct cost-benefit analysis for the use of BIM. In addition, the EC is also expected to publish a study in 2021 aiming to develop a model to measure the financial and non-financial costs and benefits of using BIM in public construction projects[291]. In turn, this will contribute to raising awareness and interest among public authorities, who will be better equipped to apply BIM through public procurement.

In this regard, it is important to highlight the work of the EU BIM Task Group (which includes members representing public bodies from 23 EU Member States[292] and three non-EU countries[293]), which is supported by the European Commission. The goal of the group was to support European BIM public sector BIM adoption with a common aim of improving the cost effectiveness and quality of public construction and the sustainability of the industry in Europe. In order to support national BIM policy developments and address issues surrounding the multitude of local programs, the EU BIM Task Group published in 2017 their Handbook for the Introduction of Building Information Modelling by the European Public Sector, which collected insights from public actors in over twenty European countries[294].

Box 5: Handbook for the introduction of Building Information Modelling by the European Public Sector[295]

Europe's public procurers, policy makers and public estate owners recognise the positive and transformative effect that digitalisation brings to both public works and the construction sector. The Task Group's vision is to encourage the common use of BIM, as 'digital construction', in public works with the common aim of improving value for public money, quality of the public estate and for the sustainable competitiveness of industry.

The handbook, published in 14 languages, provides recommendations on the introduction of BIM by the European public sector as a strategic enabler; and on the adoption of an aligned framework for BIM introduction into the built environment and construction sector. In doing so, it provides good practices; helps build a common understanding of the BIM methodology and a shared type of language; contributes to promoting a coherent introduction of BIM within the single countries.



Source: EUBIM (2017).

In addition, the EC has funded several structural reform measures related to BIM in different countries (e.g. Bulgaria, Czech Republic, Estonia, Lithuania, Poland)[296]. This is yet another way, in which the EC can foster the use of BIM in public procurement and beyond.

Data privacy and security

Beyond supporting the financing of technologies, digitalisation related strategies are expected to tackle some of the key challenges relating to data security and governance, and skills. For instance, the European

289 This figure is based on desktop research and survey. Please note that two more countries are on their way to implement BIM requirements, namely Czech Republic and Latvia

290 European Commission (2020). A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1603122220757&uri=CELEX:52020DC0662

291 See more information at: https://ec.europa.eu/easme/en/tenders/methodology-cost-benefit-analysis-use-bim-public-tenders

292 Austria, Belgium, Bulgaria, Czech Republic, Croatia, Germany, Greece, Denmark, Estonia, Finland, France, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden.

293 Iceland, Switzerland and the UK

294 EUBIM (2017). Handbook for the introduction of Building Information Modelling by the European Public Sector. http://www.eubim.eu/wp-content/uploads/2017/07/EUBIM_Handbook_Web_Optimized-1.pdf

295 EUBIM (2017). Handbook for the introduction of Building Information Modelling by the European Public Sector. http://www.eubim.eu/wp-content/uploads/2017/07/EUBIM_Handbook_Web_Optimized-1.pdf

296 See more information at: https://ec.europa.eu/info/departments/structural-reform-support_en

Strategy for Data is expected to lead to the creation of EU single market for data, where data, including confidential and sensitive data, are secure and where businesses and the public sector have easy access to huge amounts of high-quality data to create and innovate[297]. Regulations and rules on data exploitation and exchange would in turn support the uptake of digital technologies by removing/mitigating some of the risks linked to their integration in the construction sector such as cybercrime.

Still related to data, the EC also enforced a regulation on unmanned aircraft systems and on third-country operators of unmanned aircraft system (EU Regulations 2019/947 and 2019/945), to frame the growing use of drones (and their potential to contribute to economic development and job creation). The objective is to support such a potential while mitigating issues relating to data protection, privacy, noise and CO_2 emissions. Last, when talking about data protection, it is difficult not to mention the General Data Protection Regulation (GDPR) - Regulation (EU) 2016/679. GDPR sets out to protect individuals' rights in the digital age and facilitate business by clarifying rules for companies and public bodies in the digital single market[298]. This regulation has an impact on the construction sector, as companies may collect data through construction site access cards, wearable technology, sensors[299], internet of things[300] and smart systems (when we are referring to completed buildings). The use of construction software (such as those BIM related) [301] and digital building logbooks are two other ways in which personal data can be gathered and hence another area where GDPR applies. Digital building logbooks are also affected by the GDPR as their core function is collecting building-related data, some of which could be deemed as sensitive[302]. In addition, the upcoming EC Digital Act is also expected to propose clear rules framing the responsibilities of digital services to address the risks faced by their users and to protect their rights[303]. These regulations thus benefit to the construction sector, as they bring clarity about the use of drones and the data gathered through this means, favouring its sustainable and responsible growth.

Standardisation

The EC has developed a number of initiatives aiming to support the standardisation of digital technologies – for instance, CEN/TC 442 'Building Information Modelling', a technical committee of European Committee for Standardisation (CEN) on the European level aims to develop and maintain standards in the BIM domain[304]. In addition, buildingSMART international, plays a key role in supporting the adoption of common and open international standards for infrastructure and buildings (see box below). DigiPLACE, an EU funded project, also aims to create a common ecosystem of innovation, standardisation and commerce to increase the construction sector's productivity and outputs' quality in terms of buildings and infrastructure. More broadly, the EC also intends to communicate a strategy for standardisation to allow for the deployment of interoperable technologies respecting Europe's rules, and promote Europe's approach and interests on the global stage[305]. This could have a positive impact on the construction sector, which could e.g. more easily size business opportunities across EU Member States.

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297 Andruško et al. (2020). EU's new Digital Strategy for the next five years – will Europe become a trusted digital player? https://www.whitecase.com/publications/alert/eus-new-digital-strategy-next-five-years-will-europe-become-trusted-digital
298 European Commission (2020) Data protection in the EU. https://ec.europa.eu/info/law/law-topic/data-protection/data-protection-eu_en
299 See more information at: https://www.elektormagazine.com/news/gdpr-a-fateful-course-for-smart-buildings
300 See more information at: https://www.iotforall.com/iot-gdpr-opportunity-privacy-by-design
301 See more information at: https://www.letsbuild.com/blog/gdpr-in-construction
302 See more information at: https://jeffreyblaylock.medium.com/overview-of-the-eus-digital-building-logbook-report-published-jan-2021-27e510254696
303 European Commission (2020). The Digital Services Act package. https://ec.europa.eu/digital-single-market/en/digital-services-act-package
304 JRC (2017). Building Information Modelling (BIM) standardisation. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC109656/bim.standardization_1.pdf
305 European Commisison (2020). Shaping Europe's Digital Future. https://ec.europa.eu/info/sites/info/files/communication-shaping-europes-digital-future-feb2020_en_3.pdf

Box 6: BuildingSMART presence in the EU-27

In addition to national initiatives, there are also international platforms supporting the digitalisation of the construction sector. **BuildingSMART**[306] is a global community of members, partners and sponsors led by the parent body, buildingSMART International, which aims to create and develop open digital ways of working for built environment. In particular, it focuses on the creation and adoption of open, international standards for infrastructure and buildings. In addition to standards, it also provides support to construction sector visionaries, with a view to help transform the design, construction and operation of tomorrow's built assets. The community has chapters (or branches) in 13 Member States: Ireland, Spain, France, Germany, Luxembourg, Belgium, the Netherlands, Poland, Finland, Denmark, Italy, Slovenia and Austria.

3.2 Member States' digitalisation policies and initiatives

This sub-section provides an overview of what policies and initiatives Member States have put in place to support the digitalisation of the construction sector. While policymakers can opt for various strategies and instruments, this section will focus specifically on the following: digital construction policies; digital platforms; public procurement; digital building logbooks and digitalisation of building permit systems.

3.2.1 Digital construction policies

Digitalisation levels vary substantially across the EU-27. The Digital Economy and Society Index (DESI) monitors Europe's overall digital performance and tracks the progress of EU countries in digital competitiveness. By providing data on the state of digitalisation of each Member State, it helps them identify areas requiring priority investment and action.

While the different levels of digitalisation vary across the EU, all Member States have in place a variety of strategies or policies to digitalise their industrial systems, society and public administration. These strategies and their importance will be strengthened in the context of the current Programming Period and the EU Recovery and Resilience Facility[307], according to which each national recovery and resilience plan will have to include a minimum of 20% of expenditure to support digital transition. In this regard, the EC has developed a methodology to ensure investment is channelled to both infrastructure and digital capacities[308]. In particular, the EC listed seven flagships areas for reform and investments that include inter alia, clean technologies and renewables, energy efficiency of buildings, digitalisation of public administration and education and training to support digital skills.

When it comes to **digitalisation in the construction sector**, Member States follow different policy approaches, which can be categorised in two dimensions:

- **Horizontal digitalisation strategies**. These are national digitalisation policies, covering a wide range of sectors, technologies and areas. Such strategies may or may not explicitly include the construction sector.

[306] BuildingSMART, more information available at: https://www.buildingsmart.org/about/

[307] EU Recovery and Resilience Facility (2020), available at: https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en

[308] See more information at: https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en#:~:text=20%25%20for%20digital%20investments%20and,both%20infrastructure%20and%20digital%20capacities.

- **Vertical digitalisation strategies for the construction sector**. These target specifically the digitalisation of the construction sector, covering the full or part of the value chain, and specific digital technologies (such as BIM) or all digital technologies without distinction.

Those policies often include a strategy, an action plan and financial instruments as well. This signals that – whether with a horizontal strategy or a vertical strategy for construction – governments adopt a holistic approach to supporting the digitalisation of the construction sector. The landscape of digitalisation policies for the construction sector is quite diverse across the EU Member States, as shown in the table below (see more detailed information in Annex 4)[309].

Table 1: Digital Construction Policies/Strategies across the EU-27

Countries	Type of Digital Construction Policy					
	Horizontal Policy/Strategy – does not comprise construction	Horizontal Policy/Strategy – comprises construction	Vertical Policy/Strategy – targets the construction sector	Comprehensiveness		
				Strategy	Action Plan	Financial instruments
Austria		√		√	√	√
Belgium	√			√	√	√
Bulgaria		√		√	√	√
Croatia		√		√	√	
Cyprus		√		√	√	√
Czech Republic		√		√	√	√
Denmark		√		√	√	√
Estonia			√	√	√	
Finland			√	√	√	√
France			√	√	√	√
Germany			√	√	√	
Greece			√	√	√	√
Hungary	√			√	√	√
Ireland			√	√	√	√
Italy	√			√	√	√
Latvia		*[310]				
Lithuania			√	√	√	√
Luxembourg			√	√	√	√
Malta	√			√	√	√
Netherlands	√					
Poland	√					

309 This table is based on desktop research.
310 Latvia's strategy is currently under development.

Countries	Type of Digital Construction Policy					
	Horizontal Policy/Strategy – does not comprise construction	Horizontal Policy/Strategy – comprises construction	Vertical Policy/Strategy – targets the construction sector	Comprehensiveness		
				Strategy	Action Plan	Financial instruments
Portugal	√			√	√	√
Romania	√					
Slovakia	√			√	√	√
Slovenia		*[311]				
Spain			√	√	√	
Sweden			√	√	√	√

Close to 60% of Member States – 16 out of 27 – have in place policies covering or targeting the digitalisation of the construction sector, demonstrating the interest of policymakers in tackling this issue.

Among these Member States, seven opted for a horizontal strategy that covers multiple sectors, including the construction sector. Such strategies are usually wide and comprehensive encompassing the upgrading of the national digital infrastructures – in order to guarantee fast internet access to the whole population – the digital upskilling of citizens and firms and the setting up and upgrading of government e-services. When it comes to include digitalisation in the construction sector, most of the horizontal strategies approach the sector from one of these two angles:

- **E-government and electronic public services**: national governments' digitalisation strategies usually encompass the digitalisation of public services, since it is the direct channel of communication between the public administration and the citizens. Depending on the Member State, this may include the introduction of BIM in public procurement, the digitalisation of building permits system and the creation of digital building logbooks to keep all the relevant building information up-to-date and publicly available. This is the approach adopted by Croatia for instance – as show in the box below.

Box 7: e-Croatia 2020 Strategy[312]


e-CROATIA 2020 STRATEGY

- The e-CROATIA 2020 STRATEGY is a policy aiming to enhance the country's economic competitiveness and quality of life of citizens by supporting the use of information and communications technology public services. In particular, through the eRealEstate tool the services aims at creating a national database of properties' prices, for market and tax purposes.
- Land registries and cadastre system, which will integrate additional modules, along with a registry of expropriated real property. Information systems for geospatial data management, availability of spatial data via network services, and the cadastres of buildings and infrastructure will be further developed and improved.
- Permit system, where new databases will be connected to the ePermit system in the future. These will include construction products database, contractors database, auditors database, database of the information system for issuing Energy Certificates, database of public utility contributions and fees, database of certified installers of renewable energy systems, computer programme for the calculation of the energy properties of buildings.

Source: Croatia's Ministry of Public Administration (2017).

[311] Slovenia's strategy is currently under development.
[312] Croatia's Ministry of Public Administration (2017). E-Croatia 2020 Strategy: https://uprava.gov.hr/UserDocsImages/Istaknute%20teme/e-Hrvatska/e-Croatia%202020%20Strategy%20-final.pdf

- **Resource and energy efficiency for environmental impact**: the construction of new, and renovation of existing buildings is very often linked to their environmental impact – in terms of waste or greenhouse gas emissions. In this context, digitalisation is often seen as a means to build better and addressing the sustainability dimension of the construction sector – through e.g. gathering data on buildings and guarantee a more efficient energy-management. The Bulgarian strategy explicitly links the carbon reduction opportunities and the digitalisation of construction, as shown in the box below.

Box 8: Digital Transformation of Bulgaria for the period 2020-2030

In Bulgaria, the digitalisation of the construction sector is geared towards the application of the principles of circular economy, sustainable construction, energy efficiency, and the reduction of carbon emissions. In this context, the digital transformation of Bulgaria aims to contribute to resource and energy efficiency through the faster deployment of renewable energy sources and smart grids for managing energy consumption in buildings and facilities. It is expected to help reducing CO_2 emissions and achieving the objectives of the European Green Deal.

The strategy covers the entire construction life cycle: design, digital databases building on the characteristics of construction products, construction sites 3D models, digital building logbooks and facilities and their respective databases, management of constructions' operating costs, their repairs, renovations and demolition. In turn, this is expected to contribute to the optimisation of the design process, reduction of the cost of construction products, improvement of the attractiveness and competitiveness of the sector.

Part of the strategy also focuses on public administration efficiency and the quality of public services in the field of construction. In this regard, legislative changes are expected to be implemented with new energy efficiency requirements applicable to all new and existing buildings, including central heating and/or cooling, electrical mobility installations at a later stage and other solutions for smart building management. This would create an opportunity to form smart cities and build communication and digital infrastructure and capacities.

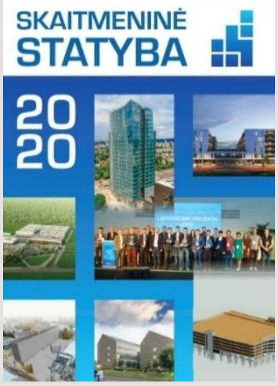
Importantly, Bulgaria, with the support of the EC SRSP programme, is also developing a (vertical) strategy aiming to support specifically the digitalisation of its construction sector[313].

Source: Bulgaria's Ministry of Transport, Information Technology and Communications (2020).

Horizontal strategies are broad, comprehensive and ambitious, as they aim to digitalise an entire country touching upon almost all aspects of the society and the economy. However, the specificities of the construction sector – and its relevance for the economy – might require more targeted interventions on the long run. In this regard, ten Member States opted for a vertical strategy, which indicate on the one hand, their commitment to supporting the digitalisation of the construction sector, and on the other hand, that such a process can be best achieved if policies are tailored to the specificities of the sector. For example, in Lithuania the Ministry of Environment of the Republic of Lithuania is preparing a National strategy for the implementation of Building Information Modelling (BIM) (see Box below). For the implementation of a BIM strategy there is a need to create state-level digitalisation measures. Part of the state-level digitalisation measures will be created by the BIM-LT project (see Box below). There are also private sector initiatives concerning BIM in Lithuania. For example, the Digital construction initiative "Skaitmeninė statyba" represents 13 associations of design and construction firms has been founded in 2014 (see Box below).

313 The technical assistance project is named "Preparing and launching a digital reform of the Bulgarian construction sector".

Box 9 The digital construction initiative "Skaitmenine statyba" in Lithuania[314]



The public body "Skaitmenine statyba" ("Digital Construction") – founded in 2014 by 13 associations – is an organisation coordinating the overall digitalisation process of the Lithuanian construction sector by:

- Forming a single information structure and coding (classification system) of the construction sector contributing to the creation of an e-environment;
- Analysing the most relevant e-solutions of digital construction available in the world and in the EU (applicable to the Lithuanian context), and foster knowledge transfer;
- Promoting the experience of e-entrepreneurship in the Lithuanian construction sector by helping introduce already available digital construction e-solutions;
- Developing international cooperation at the business and academic level with a view to developing digital construction solutions;
- Carrying out the activities of education and training in the area of digital construction solutions;

To that end, the public body and its members will contribute to developing BIM unified requirements as well as BIM standards; supporting the development of public procurement specifications; coordinating public and private digital construction related activities etc.

Sources: Skaitmenine statyba (2014).

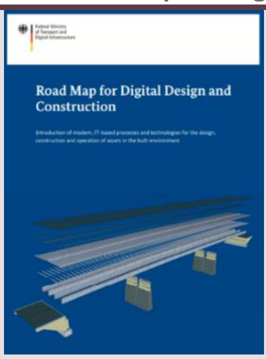
The logic of adopting a vertical strategy can stem from the public sector's direct involvement in the construction sector as a contractor of infrastructure projects and as a real estate owner. Therefore, adopting BIM in public procurement,– and other digital technologies such as digital building logbooks or permits – can help incentivise private actors to do more regarding digitalisation. This is the approach chosen by Germany, that issued a Roadmap for Digital Design and Construction in order to gradually adopt digitalisation in all its infrastructure projects – as shown in the box below. While the primary focus is on BIM, other digital technologies are targeted through the Road Map.

In addition, some countries have developed vertical digitalisation policies with a view to foster the sustainability of the construction sector. This is for instance the case of Sweden, which linked its vertical policy with the Sustainable Development Goals. In fact, Sweden's Strategic Research Agenda, Smart Built Environment[315], has been developed through broad and deep collaboration between stakeholders, and focuses on some of the central issues concerning how processes and tools in the built environment sector need to be developed. It proposes a comprehensive approach to these changes and to the modernisation of mindset, procedures and the application of digital, structured and intelligent information. Consensus on this issue is unprecedented in Sweden. Among other things, its aim is to increase productivity while providing better end-products in the form of the facilities and environments mentioned above.

[314] Skaitmenine statyba (2018). Digital construction. https://skaitmeninestatyba.lt/wp-content/uploads/2018/01/On_development_of_BIM_and_Digital_Construction_Lithuania.pdf

[315] Smart Built Environment Processes and information management in construction and facility management, available at: https://www.smartbuilt.se/library/1766/agenda-smart-built-environment.pdf

Box 10: Roadmap for Digital Design and Construction - Germany[316]



The Road Map is a strategy led by the Federal Ministry of Transport and Digital Infrastructure describing the German path towards the application of digital design, construction and operation, with a view to gradually introduce BIM, primarily in the sector of infrastructure construction(especially in the field of transport). This Roadmap was elaborated together with the private sector and aims to: i) provide some background information on BIM and its benefits; ii) explanations about the performance level 1 (more info below) and iii) examples and recommendations on BIM in terms of process, data format and contract award.

In the context of BIM, its introduction will take effect through a gradual application over time of Performance Level 1[317], to specific projects. To this end, the Ministry has also developed a set of preparatory measures required for its implementation, and additional documents meant to support private sector bidders. In practice, from mid-2017 onwards, a systematically increasing number of transport infrastructure projects will be carried out within the framework of an extended pilot phase, applying the BIM requirements of Performance Level 1. Once the basic conditions have been established, Performance Level 1 is to be applied on a regular basis to new projects in the entire transport infrastructure construction sector from the end of 2020 onwards.

Source: Germany's Federal Ministry of Transport and Digital Infrastructure (2017)

Box 11: Smart Built Environment - Sweden[318]

The Smart Built Environment Programme focuses on what will be built – or renovated and rebuilt, looking at a myriad of products and processes (including their design, form and placement) such as residential housing, schools, shops, roads, playgrounds, cycle paths and parks. In doing so, the Swedish strategy scope is quite broad encompassing what makes cities attractive and sustainable.

The Smart Built Environment Programme adopts a holistic approach to digitalisation in relation to the built environment, and aims to support the digital transformation of the private sector by helping disseminate new opportunities and business models across the sector. To do so, the Smart Built Environment includes several initiatives and programmes, which are designed following a coherent and complementary fashion to achieve a systemic impact. The digitalisation of the construction sector is hence framed as a means to strengthen the competitiveness of the sector, but more especially to contribute to a more sustainable future. In fact, its targeted impacts relate both economic and environmental dimensions:

- Reduce the environmental impact by 40%
- Reduce planning and construction time by 33%
- Reduce total construction costs by 33%
- Enable new business logic in the built environment sector

SMART BUILT ENVIRONMENT
DIGITALISATION AND INDUSTRIALISATION FOR THE SWEDISH BUILT ENVIRONMENT

As a result, the public sector demonstrates (through the Programme and the allocated budget) its commitment and support to the digitalisation of the construction sector, and incentivises private sector stakeholders to join in and help shape the future of the sector.

Source: Smart Built Environment (2019).

Last, some of these vertical policies focus specifically on digital construction technologies. For instance, France – through the PlanBIM 2022 (more information in the section below) or Ireland's Roadmap to Digital transition, focus on the implementation of BIM tackling issues such as digital skills and funding.

316 Germany's Federal Ministry of Transport and Digital Infrastructure (2017). Roadmap for Digital Design and Construction. https://www.bmvi.de/SharedDocs/EN/publications/road-map-for-digital-design-and-construction.pdf?__blob=publicationFile

317 BIM Performance Level 1 refers to the minimum criteria for the first maturity level of BIM use, including a reference process for creating, managing and sharing digital data. This is articulated around three main areas: data, processes and skills.

318 Smart Built Environment (2019). www.smartbuilt.se/in-english/about-us/

Box 12: Roadmap to Digital Transition - For Ireland's Construction Industry 2018-2021[319]

The National BIM Council developed the Roadmap to Digital Transition to increase adoption of Building Information Modelling in Ireland, thus contributing to a more productive and agile construction sector. Through this Strategy, the National BIM Council aims to work hand in hand with construction sector associations to promote the use of BIM and develop the appropriate digital skills needed amongst Irish construction firms. In doing so, the strategy aims to make the sector more competitive, in a way that it allows the latter to compete in national and international markets where BIM is widely adopted or is a requirement.

In addition, the roadmap aims to secure funding for digital transition development in Ireland, and provides performance goals. To do so, it was designed to be a living document[320] that will drive development and guide the process of reaching long-term goals of a proficient digital sector. Last, the strategy envisages the creation of a National centre of excellence on BIM to establish standards, leadership and training. However, since its completion at the end of 2017, the Roadmap has not been implemented yet.

Source: National BIM Council (2017).

Finally, the construction sector was not included in nine Member States' digitalisation strategies or policies. However, this does not mean that governments are inactive – in fact, some of these countries have in place several advanced side-initiatives on digital technologies in the construction sector, such as BIM. Therefore, these countries did not adopt specific digitalisation strategies for construction but rather financed several projects and research initiatives – like Belgium[321,322] – or simply did not intervene, adopting a more market-oriented approach, like the Netherlands[323,324] did. In Belgium, this translates to the support provided by the Brussels region's government for a Centre for Excellence in Sustainable Construction, which aims to support construction companies to incorporate technological innovations in a bid to promote more sustainable building and renovation throughout the region. In the Netherlands, several public authorities such as the public real estate agency 'Rijksvastgoedbedrijf' have put in place a BIM specification document in their tenders to foster the use of BIM in the construction sector. Another example is the Directorate-General for Public Works and Water Management in the Netherlands, which put in place its own BIM tools such as an object type library (OTL), a database (CMDB) and a BIM data room (in some cases in the tender stage a BIM data room is used to deliver the information required to make a bid in digital format)[325].

3.2.2 BIM in public procurement

The implementation of BIM has accelerated quickly in recent years and both public and private sector stakeholders are increasingly recognising the benefits to be gained by adopting it[326]. Governmental interest in BIM is driven by many factors, including increasing building quality and efficiency, achieving and managing high-quality built environment, and supporting the shift towards a green and sustainable economy[327]. In supporting digitalisation, the public sector also supports a more competitive construction sector, with

319 National BIM Council (2017). Roadmap to Digital Transition - For Ireland's Construction Industry 2018-2021 (2017). https://www.procad.ie/wp-content/uploads/2018/04/NBC-Roadmap-2018-2021.pdf

320 The Roadmap was for instance updated in 2020 to include World Economic Forum BIM Adoption Cycle 2018.

321 See more information at: https://ec.europa.eu/regional_policy/en/projects/belgium/brussels-based-centre-for-excellence-in-sustainable-construction-promotes-top-techniques-for-eco-building-and-renovation

322 See more information at: http://www2.enterprise-europemalta.com/our-events/swedish-belgian-innovation-initiative-sbii-4th-oct-17/

323 *Digital Construction in the Netherlands*, available at: http://www.bimireland.ie/2020/08/06/digital-construction-in-the-netherlands/

324 *The digital transformation of Dutch construction*, available at: https://www.letsbuild.com/blog/digital-transformation-dutch-construction

325 See more information at: https://www.linkedin.com/pulse/bim-procurement-law-netherlands-part-1-evelien-bruggeman/

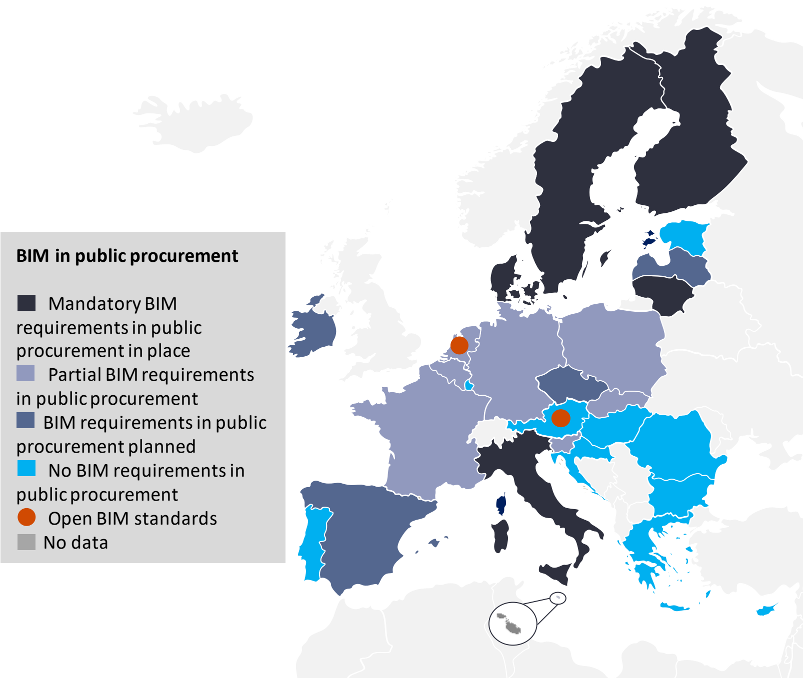
326 BIM adoption in europe current state, challenges and a vision of tomorrow; available at: https://www.magicad.com/en/bim-adoption-2020-whitepaper/

327 BIM adoption in europe current state, challenges and a vision of tomorrow; available at: https://www.magicad.com/en/bim-adoption-2020-whitepaper/

consequent overall economic growth and the creation of more and better jobs[328]. This interest has materialised by the integration of digitalisation in public procurement policies and practices, which proved to be powerful tools to foster the adoption of BIM[329]. In doing so, the public sector provides incentives to the construction sector to adopt digital technologies, which can in turn provide better and more efficient public procurement services/products and hence, better value for public money[330].

The EU directive on public procurement (Directive 2014/24/EU[331]) states that *"For public works contracts and design contests, Member States may require the use of specific electronic tools, such as of building information electronic modelling tools or similar."*. Following the directive, EU Member States have started introducing BIM requirement in their public procurement regulations and policies since the past decade - thus fostering the adoption of BIM by the sector. While Finland was the first Member State implementing IFC requirements for new buildings and operations based on integrated models (2007), Denmark was the first requiring explicitly BIM for all government office and university buildings (2008)[332]. The following approaches can be identified: i) mandatory BIM requirements in public procurement for all projects or at least for projects of a determined minimum budget ii) partial[333] BIM requirements in public procurement and; iii) planned introduction of mandatory BIM requirements.

Figure 55: Map of BIM requirements in public procurement across the EU-27[334]



Currently, Denmark, Sweden, Finland, Italy, Lithuania (please see the boxes below) and Germany have put in place mandatory BIM requirements applicable either to all projects or at least for projects of a determined minimum budget. They will be followed by Spain[335], Czech Republic (2022), Latvia (2025), which have announced their intention of putting such requirements in place in their public procurement policies.

In addition, several EU countries such as Poland, Ireland, Slovakia, Slovenia, France, the Netherlands, Belgium to name a few have put in place partial BIM requirements, often through specific public authorities (e.g. rail and road state agencies). This means that these requirements are not implemented on a systematic basis.

328 See more information at: https://www.magicad.com/wp-content/uploads/2020/04/BIM-Adoption-in-Europe-White-Paper-02042020.pdf
329 Information retrieved from interviews
330 See more information at: http://www.eubim.eu/wp-content/uploads/2017/07/EUBIM_Handbook_Web_Optimized-1.pdf
331 See more information at:https://eur-lex.europa.eu/eli/dir/2014/24/oj
332 EUBIM (2017). European Leadership in BIM. https://www.ace-cae.eu/fileadmin/New_Upload/1._ACE_Meetings/General_Assembly/Special_Sessions/2017_-_BIM_IN_EUROPE/4._Matthew_EU_BIM_Task_Group_ACE_Dec_2017_--Matthews_v1.pdf
333 Partial refers to BIM requirements put in place on an ad-hoc (as opposed to systemic) basis, by specific public authorities (e.g. road or rail authorities).
334 This figure is based on desktop research and on the ECSO survey.
335 At the level of the General National Administration, Royal Decree 1515/2018, of December 28, created the Interministerial Commission for the incorporation of the BIM methodology in public procurement. No date is available regarding the future implementation of BIM requirements in public procurement policy.

In terms of process, most countries appear to follow a similar path starting with: i) non-mandatory BIM requirement in public procurement; ii) mandatory public procurement for specific projects (or by specific institutions; iii) mandatory BIM requirements applicable to a larger scope of projects. Therefore, it would not be surprising to see more and more European countries opting for mandatory public procurement requirements in the near future. In the box below are presented some examples of existing BIM requirements across Europe.

Box 12: BIM requirements in public procurement in Lithuania

Lithuania: On 20th May 2020 the Government of the Republic of Lithuania approved the mandatory application of Building Information Modelling (BIM) methods from 1st January 2021 for the design and construction of public buildings under particular requirements (the length of the project, price of the project, inclusion to the strategic plans of the clients)[336]. BIM methods will be applied by the largest public sector clients, for other public sector clients the application of BIM methods will be recommended.

BIM methods will be used according to the Employer Information Requirements, BIM project implementation plan and BIM protocol which will be approved by the Order of Minister of Environment.

The Ministry of Environment of the Republic of Lithuania has also prepared the amendments to the Law on Public Procurement and the Law on Procurement by Clients in the Field of Water Management, Energy, Transport or Postal Services[337]. The Government of the Republic of Lithuania approved the amendments and has submitted them to the Parliament of the Republic of Lithuania. These amendments have been designed to enable the implementation of the decision taken by the Government on 20th May 2020 to accept the Ministry's' proposal that the methods of Building Information Modelling must be applied in the design, construction and installation of public sector buildings. The amendments to the laws will allow for the clients to establish requirements or criteria in the procurement documents for the application of BIM methods in cases and in accordance with the procedures established by the Government or its authorised institution.

Source: Ministry of Environment of the Republic of Lithuania (2021)

Box 13: BIM Requirements in public procurement across the EU: the examples of Denmark and Italy[338]

Denmark: **As part of its public procurement law, the Danish government published the regulation 1365, adopted in 2007** (extended in 2011 with the ICT regulation 1381, and in 2013 with the ICT regulations 118 and 119). These regulations aim to foster the integration of ICT in the construction sector, thus boosting its productivity. In practice, it required the use of BIM for public sector renovation projects since the 1st of January 2008 and for state supported social housing projects since the 1st of January 2009. Since June 2011, the Danish Parliament extended the mandatory adoption of BIM to all local and regional projects worth over EUR 2.7 million, while central government projects had a lower threshold of EUR 677,000[339]. Since April 2013, BIM has been mandatory in national, regional, municipal projects, including those on social housing[340]. The Danish government involved the academia and the industry in the preparation of the regulations, through consultations and pilot projects. This helped ensure that BIM requirements are in line with and relevant for the sector, which can then play a key role in BIM implementation.

Italy: Italy's strategy for progressive adoption of BIM (Building Information Modelling) started with approval and publication of UNI 11337 and the "BIM Decree". It provides for the mandatory application of BIM methodology starting from 2019. UNI 11337 standards – Building and civil engineering works – Digital management of construction information processes, were introduced in 2013. These standards represent the main framework of the national strategy for the digitalisation of buildings. UNI 11337 are divided into 10 parts, each one concerning a specific aspect of BIM. The BIM Decree (DM 560/2017, sometimes referred to as Baratono Decree) implements art. 23 paragraph 13 of the new Code of Public Market, drafted by the Baratono Commission. Such implementation will be done in six phases. First, since 2019, all complex projects worth

336 More information about BIM mandate: https://statyba40.lt/titulinis/privalomas-bim-metodu-taikymas/
337 More information about the amendments: https://statyba40.lt/titulinis/siulomi-viesuju-pirkimu-istatymu-pakeitimai/
338 Construction Sector Observatory (2019). Trend Paper – Building Information Modelling in the EU construction sector. https://ec.europa.eu/docsroom/documents/34518
339 CITA (2017). Global BIM Study https://issuu.com/constructionitalliance/docs/global_bim_study_bicp
340 BIPS (2014). BIM Survey 2014. https://bips.dk/files/news_files/bim_survey_2014_r0.pdf

more than EUR 100.0 million were required to adopt the BIM methodology. By 2020, the use of BIM became mandatory for any complex projects which value is equal to or exceed EUR 50.0 million. As of January 2021, BIM is required for complex projects worth EUR 15.0 million or more. By 2022, the use of BIM will be required for works which amount is equal to or greater than the threshold defined in Article 35 of the Public Contract Code (EUR 5.2 million for works contract). As of January 2023, BIM will be required for works amounting to EUR 1.0 million or more. The last step, planned in 2025, is to expand BIM to all projects, complex or not, up to amounts of less than EUR 1.0 million.

Source: European Construction Sector Observatory (2019).

Currently, three Member States (Italy, the Netherlands[341] and Austria[342]) have open BIM standards[343]. These are important as they support a transparent workflow among project members, who are not obliged to adopt specific software. Moreover, a common language allows industry and government to generate projects with transparent commercial engagement, comparable service evaluation and assured data quality. Adoption of Open BIM is encouraged by public bodies, which favour open standards before proprietary alternatives, because vendor independence, compatibility, prospect of long-term support and commercial neutrality are fundamental in the public procurement process[344].

Last, if public procurement is recognised by all actors from the public and private sector as one of the key means government have to foster digitalisation of the construction sector, it is important to highlight that their pallet of actions can be broader. The results of the survey[345] show that 22 EU Member States have implemented a national working group on BIM; nine MS have implemented a BIM/Digital Construction Strategy; and 21 MS have implemented BIM Standards and/or guidance respectively (see a non-exhaustive overview of BIM policy support measures in Annex 5).

Table 2: Policy or measure is in place to support BIM adoption, beyond public procurement[346]

	BIM/Digital Construction Strategy	BIM Standards and/or guidance	National working group on BIM
Austria			
Belgium			
Bulgaria			
Croatia			
Cyprus			
Czech Republic			
Denmark			
Germany			
Greece			
Estonia			
Finland			
France			
Hungary			
Ireland			
Italy			

341 VISI is a Dutch standard that forms the basis of communication and information exchange between building parties. COINS refers to a Dutch integrated, complementary standard for exchanging digital information and with support for Systems Engineering. CB-NL is a Dutch standard that connects object libraries for objects and spaces in the built environment.
342 ÖNORM A 6241-1 and A241-2, developed by the Austrian Standards Institute.
343 Open BIM standards are a standard format allowing for interoperability and data exchange in a secure way, without errors and/or loss of information. In practice, this means that open formats can be read and edited by anyone.
344 See more information at: https://www.magicad.com/wp-content/uploads/2020/04/BIM-Adoption-in-Europe-White-Paper-02042020.pdf
345 The results for Poland, Slovakia and Slovenia are based on desk research.
346 This table is based on the survey conducted by the European Construction Sector Observatory.

	BIM/Digital Construction Strategy	BIM Standards and/or guidance	National working group on BIM
Latvia	Present	Absent	Present
Lithuania	Present	Present	Present
Luxembourg	Absent	Present	Present
Malta	Absent	Absent	Absent
Netherlands	Absent	Present	Present
Poland	Absent	Present	Present
Portugal	Absent	Present	Absent
Romania	Absent	Present	Present
Slovakia	Absent	Present	Present
Slovenia	Absent	Present	Absent
Spain	Present	Present	Present
Sweden	Absent	Present	Present

Present *Absent*

Source: ECSO survey, 2020

Governments can also support digitalisation and BIM implementation by i) supporting educational and skills development (allowing to train a new generation of BIM specialists); ii) helping develop, together with businesses, BIM standards that can in turn foster its interoperability[347]. These other policy areas should be seen as complementary to BIM public procurement requirements, as illustrated by the Plan BIM 2022, which is part of the Digital Transition Plan in the Building (PTNB), as described in the box below.

Box 14: Actions FRANCE took to foster BIM implementation, beyond public procurement requirements[348]

The BIM 2022 Plan builds on the Digital Transition Plan in the Building (PTNB), which has been in place since 2015 to put in place a solid framework for the digitalisation of the construction sector. In particular, the BIM 2022 Plan aims to generalise the use of digital technology in buildings by 2022; and mobilise and support the building sector, by providing professionals with practical methods and tools to spread the use of digital technologies.

The KROQI is a collaborative platform launched in 2018 as part of the PNTB, to help build SMEs' BIM capacities. The KROQI offers free BIM mock-ups, and access to tools supporting BIM processes and collaborations such as platforms for BIM models sharing, visualisation and checking.

Another initiative (outside of the PNTB) supported by the French government is the EduBIM, a network of BIM teachers, trainers and researchers, collaborating with the industry and in charge of supporting BIM implementation through research and new learning methods. This includes several universities, such as Ecole des Ponts ParisTech, École Spéciale des Travaux Publics or Ecole Superieure d'Architecture de Marseille.

Source: Ministère de la Cohésion des Territoires (2018).

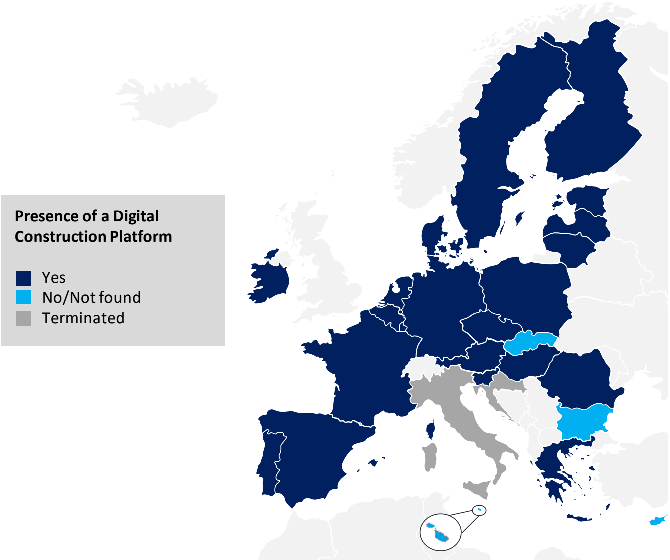
[347] ECSO (2019). BIM in the European construction sector. https://ec.europa.eu/docsroom/documents/3451
[348] Ministère de la Cohésion des Territoires (2018). Plan BIM 2022. https://plan-bim-2022.fr/

3.2.2 National digital construction platforms

Digital construction platforms are virtual or physical platforms gathering private and public stakeholders, aiming to support the integration of digital technologies in the construction sector. These can also take the shape of "associations". Digital construction platforms perform an important function: in a sector characterised by its fragmentation (in terms of number of SMEs and number of stakeholders along the value chain), these platforms allow coordination. Therefore, having a unique place where different stakeholders can meet, exchange best practices on digitalisation and find potential synergies, has a considerable added value. In this regard, it is important to highlight the role of DigiPLACE, the EU framework allowing the development of future digital platforms as common ecosystems of digital services that will support innovation, commerce, etc[349].

Digital construction platforms, as further developed in the section below, can have one or several functions, including networking, knowledge sharing and training, facilitating access to public funds or establishing industrial standards etc. In that sense, the platforms, as highlighted in the different examples of this section, may differ in terms of their own nature: some are industrial platforms, supporting companies to develop standards and guidelines on specific digital technologies such as BIM, some are closer to educational type of platforms providing courses and supporting the digital capacities of companies such as KROQI which is mentioned above; and some are rather space for public-private sector dialogue as in the case of the Kirahub platform (more information below).

Figure 56: Presence of Digital Construction Platforms in the EU-27



The figure aside maps some of the digital construction platforms identified through this study[350]. It is important to mention that some Member States host research centres or innovation hubs focused on spreading digitalisation in the whole country, without a sectoral distinction which, therefore, cannot be classified as digital construction platforms. This is the case of **Sofia Tech Park**[351] in Bulgaria and the **CROBOHUB Croatian Robotics Digital Innovation Hub**[352] in Croatia. Likewise, national platforms which are part of international platforms such as BuildingSMART, were not accounted for.

Overall, 23 Member States – roughly 85% of EU countries – host such platforms. In addition, Croatia hosted platform initiatives in the past, but they are now terminated.

The table below provides further information on the platforms, by looking at their scope, and whether they are public or market-led (see Annex 6 for more detailed information). In doing so, this table reveals that while most platforms adopt a broad focus on digitalisation, 25% of them focus on BIM – showing that the latter technology benefits from high traction (also reflecting its higher level of maturity).

349 See more information at: https://www.digiplaceproject.eu/
350 Based on the desktop research and ECSO survey. No digital platform was found in the context of Slovakia, Croatia and Bulgaria.
351 Sofia Tech Park, more information available at: https://s3platform.jrc.ec.europa.eu/digital-innovation-hubs-tool/-/dih/1399/view
352 CROBOHUB Croatian Robotics Digital Innovation Hub, more information available at: https://s3platform.jrc.ec.europa.eu/digital-innovation-hubs-tool/-/dih/1474/view

Table 3: Digital Construction Platforms across the EU-27[353]

Countries	Digital Construction Platform			
	Number of Digital Construction Platform(s)	Focused on Digitalisation in Construction broadly	Focused on BIM only	Public Initiatives or facilitator of Public/Private collaboration
Austria	1	√		
Belgium	4		√	
Bulgaria	Not found			
Croatia	Terminated	√		√
Cyprus	Not found			
Czech Republic	2	√	√	√
Denmark	1	√		
Estonia	2	√		√
Finland	3	√		√
France	2	√	√	
Germany	2	√	√	
Greece	3	√	√	√
Hungary	2	√		
Ireland	3	√	√	√
Italy	Terminated	√		
Latvia	4	√		√
Lithuania	3	√		√
Luxembourg	4	√		√
Malta	Not found			
Netherlands	4	√		
Poland	2	√	√	
Portugal	3	√		
Romania	1		√	
Slovakia	Not found		√	√
Slovenia	1		√	
Spain	3	√	√	√
Sweden	2	√	√	

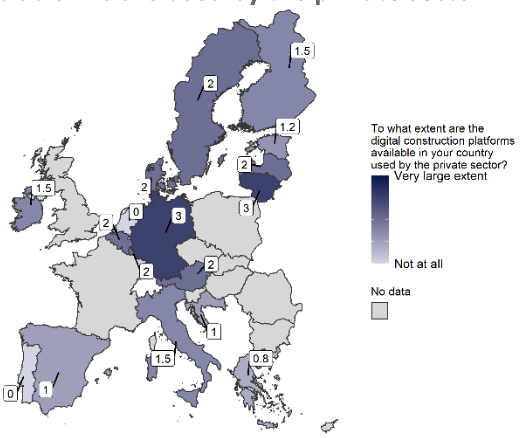
[353] This table is based on desktop research and ECSO survey. No digital platform was found in the context of Slovakia, Croatia and Bulgaria.

Box 15: Example of BIM focused digital construction platform: czBIM – Czech Republic[354]

The association Odborná rada pro BIM, z. s. was founded in 2011 with the aim of supporting the development of digitalisation processes in the field of construction in all phases of design, construction, operation and maintenance of buildings in the Czech Republic. To do so, it focuses specifically on the development of BIM through activities relating to standardisation, promotion and dissemination. It is primarily a market-led initiative, representing the interests of the private sector, thus ensuring that the implementation of BIM in the Czech Republic reflects the needs, interests but also constraints of the actors on the ground. The main activities of this independent association are to create methodologies and standards necessary for practice, especially in the interest of the members of the association, thus facilitating the adoption of BIM in the sector; cooperate with the public administration in the preparation and implementation of the necessary legislation and standardisation; and educate and train the professional public, cooperate with secondary schools, universities and other professional organisations.

Source: czBIM (2020).

Figure 57: Extent to which digital construction platforms are used by the private sector

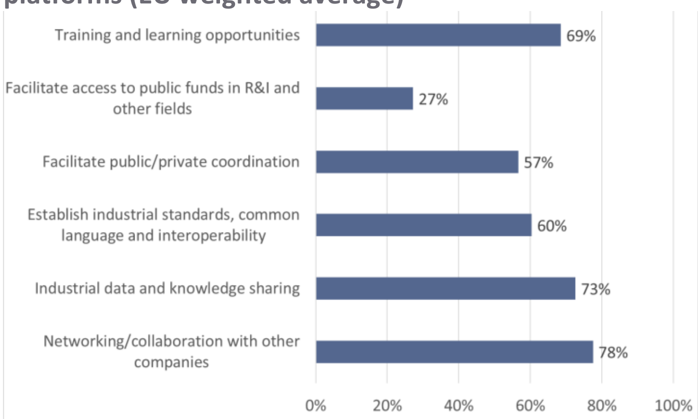


Source: ECSO survey, 2020

Before providing further details on the functions and the roles that these digital construction platforms play, it is important to note that the survey carried out for this report revealed that according to stakeholders, these platforms are used to a small or moderate extent – as shown in the figure aside. This result may be influenced by the inherent fragmentation of the construction sector; and indicate a limited appetite from businesses in such a type of collaborative initiative.

Digital construction platforms can have multiple functions, from networking with other companies, to sharing industrial data and knowledge, establishing industrial standards, common language and interoperability, facilitating public/private coordination but also access to public funds in R&I and other fields, and accessing training and learning opportunities.

Figure 58: Main functions of the digital construction platforms (EU weighted average)[355]



Source: ECSO survey, 2020

354 czBIM (2020). https://www.czbim.org/info/o-czbim
355 Figure based on ECSO survey.

Because of the aforementioned fragmentation of the construction sector, one of the prime roles and motivations for companies to join digital construction platforms is to network and collaborate with other peers with a view to build synergies. This function is part of 78% of the digital platforms surveyed as part of this report. Limited knowledge of digital technologies and their market potential is another barrier to digitalisation that construction platforms aim to address. Hence, digital construction platforms offer their members with the opportunity to access and share industrial data and knowledge, which allows them to better understand the trends and practices in the sector. This is the case of e.g. Kira HUB in Finland and SIBIM[356] in Slovenia, which are mainly oriented towards networking and creating opportunities to share knowledge about digitalisation in construction sector.

Box 16: KIRA Hub – Finland [357]

KIRAHub is a non-profit association in the construction sector that builds on one of the Finnish government's project – KIRA Digi, and which acts as a catalyst for the sustainable digitalisation of the built environment. The objective of this platform is to bring together different ideas, goals and perspectives on how to make the construction sector digitalised and sustainable. The hub hosts public and private stakeholders and supports cross-sectoral dialogues. Last but not least, KIRAHub has elaborated a strategy to make Finland a pioneer in the exploration of the concept of built environment, through digital techniques.

Source: KIRA Hub (2020)

The third and fourth most common function offered by digital platforms relate to training and learning opportunities (69%) and the development of standards and common language (60%) (see figure above). This in turn facilitates the adoption of digital technologies by improving their interoperability and addressing the need for skills. This is the case of the construction platform KROQI – Edu BIM in France, which systematically delivers trainings on digitalisation, and the BIM Portal[358] in Belgium, which aims at being a BIM-awareness information point.

Last, the functions related to public-private coordination and access to public funds are not often offered by platforms, indicating their potential limited relevance, according to the survey's respondents. This might signal that most of the platforms analysed through the survey are more market-oriented. However, the role of such platforms as a coordinator of public-private initiatives should not be overlooked. Construction companies might want to use these platforms to coordinate with public authorities on regulations and standards regarding BIM for instance. This is the case of the Latvia's Association for Construction Industry Digitalisation, and Estonia's Eehitus[359], which aim specifically at ensuring coordination between public and private stakeholders when it comes to elaborate digitalisation policies in construction, such as BIM standards and BIM requirements in public procurement.

Box 17: Association for Construction Industry Digitalisation - Latvia[360]

The Association for Construction Industry Digitalisation is an association founded in 2016. It brings together experienced professionals in the construction and technology sector who understand the difficulties and challenges of the construction process, with a view to come up with adequate solutions.

More specifically, the association's mandate relates to

[356] See more information at: http://sibim.si/en/about/
[357] KIRA Hub (2020). http://sibim.si/en/
[358] https://www.bimportal.be/
[359] Eehitus, available at: https://eehitus.ee/
[360] Būvniecības Industrijas Digitalizācijas asociācija (2020). https://buvid.lv/en/homepage/

introducing and training the sector to apply new digital processes and technologies, thereby improving the efficiency of construction processes. To do so, it supports consultation of the public and private sector in the field of digitalisation to ensure a proper coordination between public and private actors. This collaboration takes place in the context of e.g. the development of new legislation. It further helps develop and implement construction tools and technologies such as BIM and robotics[361] in the construction sector in Latvia, with a view to foster sustainability and efficiency in the sector.

Source: Būvniecības Industrijas Digitalizācijas asociācija (2020)

3.2.4 Digitalisation of the building permit systems

A building permit is the final authorisation, granted by public authorities, that gives permission to start the construction phase of a building project. The permit is part of a planning process with the aim of guaranteeing a sustainable and controlled development, benefiting communities, environment and economy[362,363]. The process of issuing a building permit consists of several steps, where a great number of stakeholders is involved, using many pieces of information. As a consequence, the building permit process is considered as a promising use case for automation via digital data about buildings and the built environment[364,365,366].

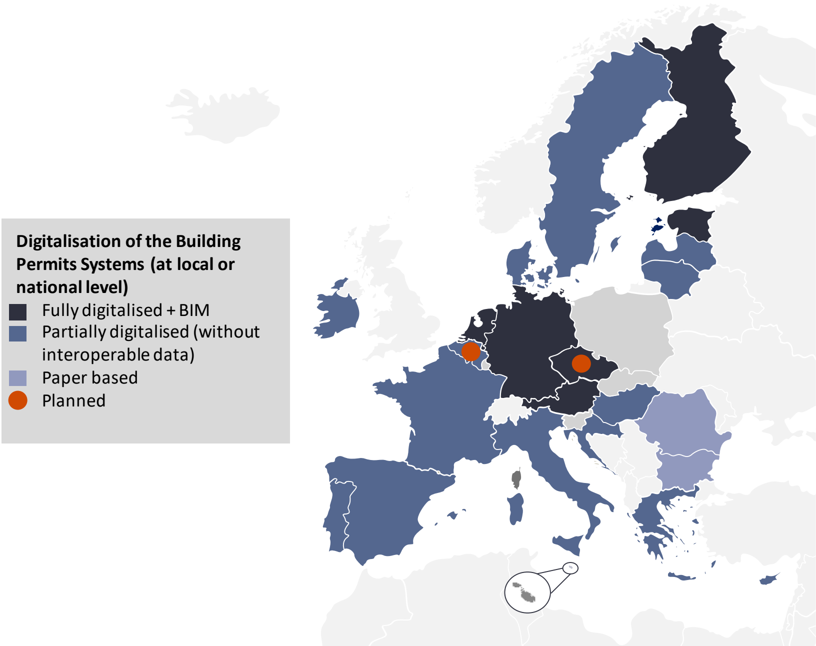
To foster the development of digital building permit system across Europe, the EC developed the e- Europe strategy (e-Europe 2003), which entails the obligation for Member States to put in place an electronic application for Building Permission by 2005 (later extended to 2020). The benefits of adopting a digital building permit process are best illustrated in a recent study conducted in the context of Estonia[367]. A cost/benefit analysis revealed a potential saving of more than EUR 500,000 per year, without taking into account the advantages and savings derived from the improvement in rules clarity and interpretations, which translated in a reduced amount of time and effort spent. Another study[368] also highlights a possible saving of 45 FTEs (full time equivalent) workforce per year, with an increase in efficiency of about 8-10% in workload[369]. In addition, the digital system is available around the clock, and thanks to the electronic archive, progress of applications can be tracked. Building inspectors are able to take electronic plans and documents out on-site, as drawings can be viewed on screen and redline comments can be made. Work completed outside of the office can thus be synchronised with the main system[370]. As a result, there has been an increasing interest in digital permit processes. This interest even extends in some cases on how the use of 3D information systems could be relevant for improving both the efficiency and the consistency of the permit processes, forming a core element of a move to fully digital planning and permitting.

Referring to the digitalisation of the building permits system, it is possible to distinguish between three main stages of development. The first stage is the paper-based building permit system, hence completely not digitalised. Paper-based building permit processes are an error-prone and time-consuming activity that

361 See more information at : https://www.youtube.com/watch?v=-u-WFAeeCvQ
362 Siew, Balatbat & Carmichael (2013). A review of building/infrastructure sustainability reporting tools (SRTs). Environment, 2(2), 106-139
363 DCLG - Department for Communities and Local Government (2015). Plain English Guide to the Planning System.
364 Eastman, Lee & Jeong (2009). Automatic rule-based checking of building designs, Autom. Constr., 18(8),1011–1033.
365 Lee, H., Lee, J.K., Park, S., Kim, I., 2016. Translating building legislation into a computer-executable format for evaluating building permit requirements, Automation in Construction. 71, 49–61. https://doi.org/10.1016/j.autcon.2016.04.008.
366 Noardo et al. (2020). Integrating expertises and ambitions for data-driven digital building permits. https://www.researchgate.net/publication/344337948_INTEGRATING_EXPERTISES_and_AMBITIONS_for_DATA-DRIVEN_DIGITAL_BUILDING_PERMITS_-_The_EUNET4DBP
367 Future Insight Group (2019). Technical report for contract SRSS/C2019/024 -Introducing a Building Information Model (BIM)-based process for building permits in Estonia. https://eehitus.ee/wp-content/uploads/2019/11/2019-07-19-BIM-based-building-permits-Technical-Report.pdf.
368 PwC (2019). Mapping, optimizing and adjusting for the introduction of e-construction of the procedures of the Register of Buildings – Final report https://eehitus.ee/wp-content/uploads/2019/07/MKM_PwC_EHR_optimizing_Register_of_Buildings_final_report_ENG.pdf
369 Noardo et al. (2020). Integrating expertises and ambitions for data-driven digital building permits. https://www.researchgate.net/publication/344337948_INTEGRATING_EXPERTISES_and_AMBITIONS_for_DATA-DRIVEN_DIGITAL_BUILDING_PERMITS_-_The_EUNET4DBP
370 Belos et al. (2015). Electronic building permission system: The case of Greece. https://www.sciencedirect.com/science/article/pii/S1877705815031501

may lead to ambiguity, inconsistency in assessments and delays over the entire construction process[371]. The second stage regards building permits systems that are partially digitalised (i.e. some of the steps – or even all the steps – of the application for a building permit can be managed online). This stage of digitalisation may rely on PDFs format type of documents, allowing users to download forms and upload documents, and does not exploit the full potential of digitalisation. In other cases, the digital transformation goes one step further by providing for interoperable data – which allows for the exploitation of data and more generally for a more sophisticated approach to building permits systems. Finally, the third stage is a complete digitalisation of the building permit system, characterised by a fully digital processes with machine readable documents allowing for the exploitation of data. The final evolution relates to the compatibility with BIM, allowing to have a fully automated process with 3D models.

Figure 59: Digitalisation of building permits systems across the EU-27[372]



Source: ECSO survey, 2020

In most EU countries, the process of issuing building permits is typically administered at local level – i.e. by municipalities[373]. Hence, within a country, the building permit system may be digitalised to a different extent, with municipalities providing fully digitalised systems, which may even integrate 3D models, and others relying on paper format. In this context, it is important to specify that the below overview of the digitalisation of the building permits systems is based on the survey results, which focus on the country rather than the municipality level. The objective of the survey was to get a general picture of the state of play of building permit systems in the different EU Member States[374]. Likewise, the survey classifies the level of digitalisation following previously established classification (see more information below)[375]. Such an approach did not include in its scope the distinction between the degree of sophistication of "partial" digital building permits – i.e. whether they rely on PDF format documents or other formats.

As shown in the figure aside, the results of the survey and the research show that the adoption of electronic building permits system across the EU-27 is relatively high. Almost all EU countries – with the exceptions of Bulgaria and Romania – have their permits system digitalised – though to different extent as described later on in this section.

[371] Malsane, S., Matthews, J., Lockley, S., Love, P.E.D., Greenwood, D., 2015. Development of an object model for automated compliance checking, Automation in Construction, vol. 49, pp. 51-58.

[372] The map is based on the survey results and desktop reasearch.

[373] Eurostat (2012). PEEIs in focus. https://ec.europa.eu/eurostat/documents/3888793/5852117/KS-RA-12-009-EN.PDF/d2df8401-34f0-47aa-8088-d19ee1c2a5d3?version=1.0

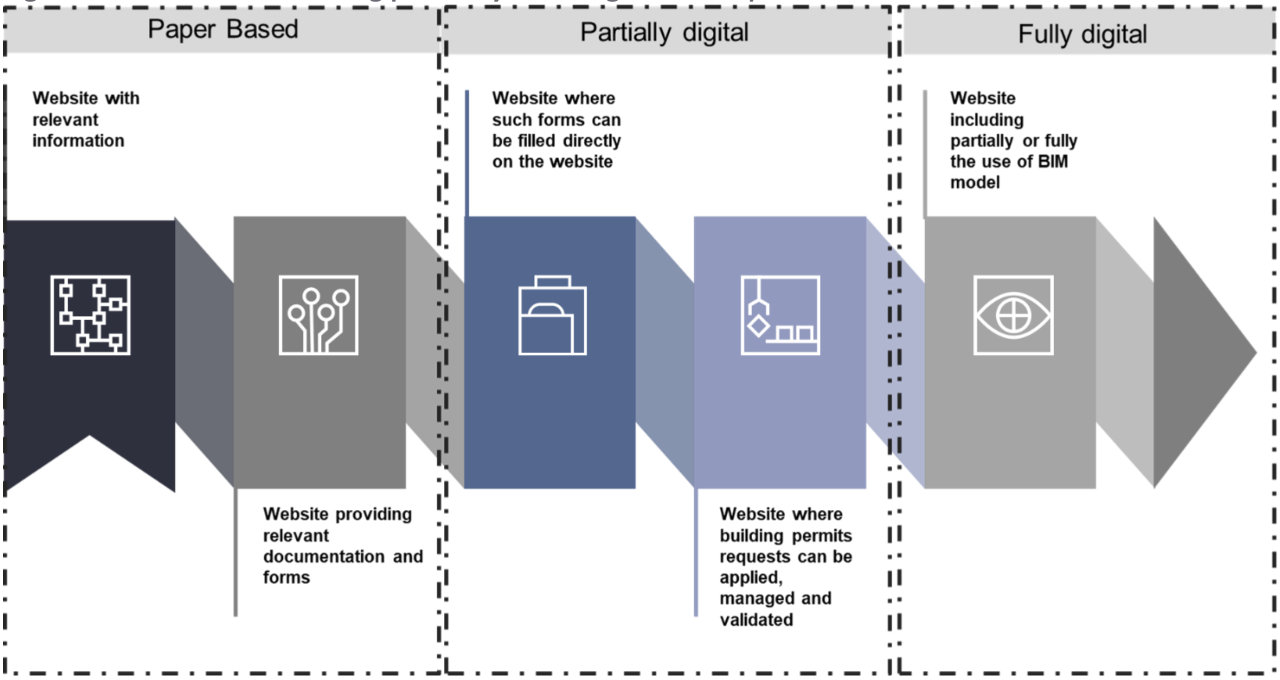
[374] The readers interested in getting more accurate results will need to refer directly to the municipality website thy may be interested in.

[375] Belos et al. (215). Electronic building permission system: The case of Greece.

Put in practice, this means that in 14[376] EU countries have a partially digitalised permit system, where building permits can be managed at least partially – or even fully – online but the system does not necessarily provide interoperable data. Applicants can submit all the documents in electronic formats through the website of the competent public authority.

Importantly, five EU Member States (Germany, Estonia, Netherlands, Austria and Finland) have started coupling BIM with their permit systems, allowing to have a fully automated process with 3D models, and Czech Republic plans to do the same. In this regard, it is interesting to note that Estonia is currently supported by the EC to go one step further and conduct preliminary analysis of AI adoption in the field of environmental permits, charges and supervision. The table below provides an overview of the level of digitalisation of the digital permits in Europe, based on the survey's answers. In addition, the results of the survey were compared and complemented with the ECSO Country Fact Sheets. As a permit system digitalises, it moves from providing i) a website with relevant information; to ii) a website providing relevant documentation and forms (however the building permits system is still paper based); to iii) a website where such forms can be filled directly on the website, to iv) a website where building permits requests can be applied, managed and validated; to v) a website including partially or fully the use of BIM model.

Figure 60: Overview of building permit systems digitalisation process



376 Belgium is currently supported by the EC to implement a digital platform for building permits.

Table 4: Extent to which the building permit system process is digitalised in the EU

	Paper based		Partially digitalised (without interoperable data)		Fully digitalised + BIM
	A website is available with information to start the procedure is still paper based	The website offers the possibility to obtain the paper form to start the procedure	The website offers the possibility to obtain a building or renovation permission in electronic form	The building permission can be applied, managed and validated electronically	The building permission procedure includes partially/fully the use of BIM
Austria					Yes
Belgium				Planned[377]	
Bulgaria	Yes				
Croatia				Yes	
Cyprus			Yes		
Czech Republic					Planned[378]
Denmark				Yes	
Estonia					Yes
Finland					Yes
France			Yes		
Germany					Yes
Greece				Yes[379]	
Hungary			Yes		
Ireland				Yes	
Italy				Yes[380]	
Latvia				Yes	
Lithuania				Yes	
Netherlands					Yes
Portugal				Yes	
Romania	Yes				
Spain				Yes	
Sweden				Yes	

Source: ECSO survey, 2020

377 European Commission (2020). 2020 European Semester. Country Report Belgium 2020.
378 EC (2020). National Reform Programme of the Czech Republic, 2020.
379 ECSO (2020). Country Fact Sheet Greece.
380 ECSO Survey.

Importantly, as aforementioned, the building permit system is characterised by its local dimension as such service is often offered and administrated by municipalities[381]. Therefore, while some Member States can host pioneering digital building permit initiatives led by municipalities, it does not necessarily mean that such innovations are extended and/or applied at the national level. In Germany for instance, building permit system differs across the country, with local/municipal initiatives – as in the case of Berlin presented in the box below.

Box 18: Electronic construction and approval procedure (eBG) - Berlin, Germany[382]

Based on a step-by-step concept, the Federal State of Berlin has introduced a standardised electronic material procedure for the building inspection authorities. Now, permit applications can be submitted, processed, forwarded and approved without discontinuity. Construction supervision is supported by the system. The new procedure helps to shorten the processing times of processes.

In turn, its use has continuously been increasing in recent years. In 2014, a total of almost 52,000 applications were processed by the Town of Berlin MA system - an increase of 30% compared to 2011. Almost 4.5 million documents and building templates are stored in the document management system of the specialist procedure. The number has tripled compared to 2011. More than 26,000 online information were obtained from applicants in 2014.

Source: Federal State of Berlin (2020).

In contrast, there are also examples of electronic permit systems implemented at the national level, such as the *eDozovola* system in Croatia that is available in all the country's municipalities with the exception of Zagreb. In Italy, a common platform for building permit has been developed by the Ministry of Economic Development together with ANCI (Association of City Councils) and UNIONCAMERE (Chamber of commerce Association). Through the platform, every city council can achieve its own building permit on-line service. Currently, on a total of 8,000 cities in Italy, 3,400 have joined the platform.

Box 19: eDozvola - Croatia[383]

Through the "eDozvola" system, applications to issue (and hence obtain) permits for the construction and use of buildings can be filled in electronically as well as updating the status of the application.

eDozvola

To do so, a unique information system deployed by the Ministry of Physical Planning, Construction and State Property has been implemented since 2014, with a view to issue construction acts and conducting procedures under the Physical Planning Act and the Construction Act - "ePermit". The system is implemented in the administrative departments of counties, large cities and cities of county headquarters that perform licensing activities, except for the City of Zagreb. The latter uses the system "eDozvolaZG" connected with the module "eConferences" of the system "ePermit" of the Ministries of Physical Planning, Construction and State Property 2020, to process acts in the field of spatial planning and construction. Applicants can fill in all the necessary information through the public portal, and it is possible to add attachments and projects, and at any time during the applications process.

The main goal of the centralised system is to make public services more efficient and of better quality through a simple, fast and digital procedure. The functionalities of the "eDosvola" system ensure a uniform procedure for obtaining documents for the entire territory of the State, enable clerks to process cases faster and more efficient administrative processes, but also a digital archive of all attachments related to the application. Thanks to its

381 In fact, in nearly all countries the permits are issued by some kind of local/regional authority. The main exception is Malta where there is a national body that issues building permits. See more information at Eurostat (2012). PEEIs in focus. https://ec.europa.eu/eurostat/documents/3888793/5852117/KS-RA-12-009-EN.PDF/d2df8401-34f0-47aa-8088-d19ee1c2a5d3?version=1.0

382 Federal State of Berlin (2020). Electronic construction and approval procedure (eBG). https://www.berlin.de/ebg/

383 Ministry of Physical Planning, Construction and State Assets (2020). eDozvola. https://mgipu.gov.hr/default.aspx?id=8144

adoption, the process of issuing building permits is now faster. In addition, the system provides legal security to the applicants – thus ensuring the quality of the process which translates in less time and efforts on both the public sector and applicants' side.

Source: Ministry of Physical Planning, Construction and State Assets (2020).

Moving forward, some municipalities have upgraded their digital building permit system by coupling them with BIM, in order to exploit its full potential. Despite a recent rise in interest for the topic and an increased awareness of its benefits, such application is still at its infancy stage: according to the survey conducted, only three countries claimed that the procedure of the building permission includes partially/fully the use of a BIM model. That said, there are EU countries (such as the Netherlands, Sweden and Estonia) interested in linking BIM with their digital building permit system, as shown by the some of the recent pilots and larger projects being developed[384].

Box 20: Growing global and European interest in BIM-based Building Permit Process Automation[385]

Early experience in BIM-based Model Checking (BMC) solutions in Norway and the Netherlands demonstrated that digital processes are often faster and cheaper than manual processing. In fact, according to KIRAHub, the results indicate that development of an automatic compliance-checking platform will return ten times the investment required.

As a result, many building authorities have started taking the first steps towards implementing BMC in the building permit process. This is best illustrated by a recent BIM-based Building Permit Process Automation Seminar in Tallinn, Estonia in 2020, where around 350 participants from more than 20 different countries participated. More specifically, prototype solutions were presented from Estonia[386], Finland[387], Germany, the Netherlands and UK.

Source: Kirahub (2020).

In particular, some municipal initiatives of BIM-based permits systems have been implemented in Finland and in the Netherlands. Thanks to the KIRA-digi services[388] and the Sova3D software[389], the municipality of Vantaa[390] introduced a digital building application and permission based on IFC model checking through artificial intelligence. The checking is based on a set of pre-established rules, which are supported by algorithms which analyse the model's component. This checking applies to apartment buildings and private houses made specifically for building permission office and using Finnish building law requirements[391]. This e-permitting system operates on BIM and is GIS-enabled allowed improving efficiency by 30 per cent[392] since its inception in 2014 (less employees are required). In the Netherlands, some initial experiments to introduce GeoBIM in the building permits system began in recent years[393], e.g. in the Rotterdam municipality[394], signalling a rising interest on the topic across the country.

[384] Belos et al. (2015). Electronic building permission system: The case of Greece. https://www.sciencedirect.com/science/article/pii/S1877705815031501

[385] Kirahub (2020). BIM-based Building Permit Process Automation Seminar (2020). https://kirahub.org/en/pre1-bim-based-building-permits/

[386] See more information at: https://kirahub.org/wp-content/uploads/2020/02/10.30-EE-introducing-a-BIM-based-permits-process-in-Estonia-Jaan-Rick.pdf

[387] See more information at:https://kirahub.org/wp-content/uploads/2020/02/11.15-FI-Vantaa-BIM-permit-Pekka-Jekaterina.pdf

[388] Kirahub (2020). KIRA-digi. http://www.kiradigi.fi/en/experiments/ongoing-projects/bims-in-building-control-inspections.html

[389] Sova3D software, available at: http://www.sova3d.fi/wp/

[390] Virkamäki et al. (2020). Challenges and experiences to implement digital building application and permission in Finland IFC model checking using artificial intelligence and idea of supplementing city model". https://kirahub.org/wp-content/uploads/2020/02/11.15-FI-Vantaa-BIM-permit-Pekka-Jekaterina.pdf

[391] See more information at: https://kirahub.org/wp-content/uploads/2020/02/11.15-FI-Vantaa-BIM-permit-Pekka-Jekaterina.pdf

[392] See more information at: https://rescon.com/news/files/July08-2019TheDailyCommercialNews.pdf

[393] Van Berlo, Dijkmans, Stoter (2013). Experiment for integrating Dutch 3D spatial planning and BIM for checking building permits. ISPRS- Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci. - 8th 3DGeoInfo Conference & WG II/2 Workshop, Istanbul, Turkey, 27–29 November 2013, II-2/W1

[394] TUDelft (2020). GeoBIM for Building Permit in Rotterdam. https://3d.bk.tudelft.nl/projects/rotterdamgeobim_bp/

Box 21: The European Network for Digital Building Permits [395]

The European Network for Digital Building Permits is composed of research institutions, public institutions and private sector actors, and aims to define a common vision and strategy for the digitalisation of building permit systems. In doing so, this Network is expected to contribute to i) fostering a building permit process that is more efficient and automated; ii) supporting to rule interpretation and information requirements in becoming as simple and as machine readable as possible; and iii) supporting the wide adoption of interoperable technologies based on open standards.

To do so, part of the work focuses on issues related to interoperability, procedures and data optimisation, standardisation and good implementations. In addition to these, the Network also focuses on empowering the public officers to effectively switch their mindsets from paper based to digital solutions. The approach of the Network is hence rather holistic by focusing on both developing the offer but also the demand for digital building permit systems.

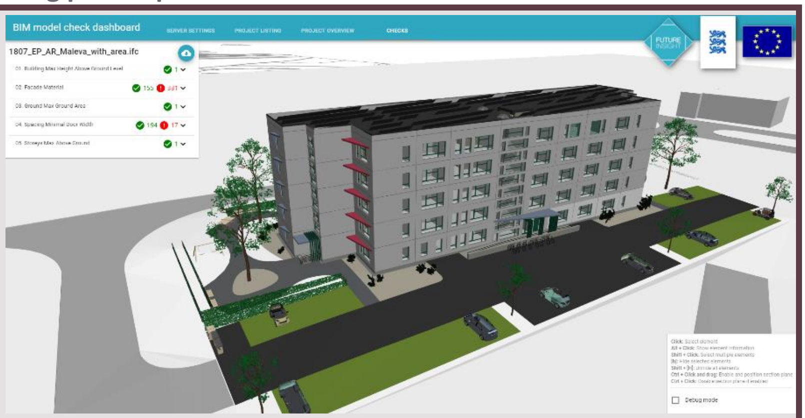
Source: The European Network for Digital Building Permits (2020).

In parallel, nation-wide initiatives exist in Estonia (please see the box below), **and in Sweden**[396]**.** In the latter country, there has been a national project on defining GeoBIM data delivery specifications[397] and linkages to automatic rule checking[398] as part of the wider 'SmartBuiltEnvironment'[399] project. Last, in Italy, public administrations have started to look at the BIM-based code checking topic since 2013, when a first pilot project was launched by the public works authority of Lombardia and Emilia Romagna[400]. Other examples have been developed later involving public administrations at region, province and city level.

Box 22: A prototype of the BIM-based building permit procedure - Estonia[401]

In 2019, the Estonian Ministry of Economic Affairs and Communications started analysing the possibilities for automating the building permit process using BIM-based workflows. The project aimed to achieve three main objectives:

1. find out the technical requirements for implementing a BIM-based process in EHR (Estonian Building Registry);
2. to specify verifiable claim types,
3. to create a Proof of Concept and User Interaction (UX) mock-ups of the EHR user interface.



The project was made in collaboration with a Dutch consulting company Future Insight and was funded by the European Commission's Structural Reform Support Program.

Source: E-ehitus (2019).

3.2.5 Digital building logbooks and digital registries

A digital building logbook is a common repository for all relevant building data. Building logbooks can be sometimes referred to as building passports. Building logbooks aim to increase transparency and trust among owners, tenants, financial institutions, construction sector stakeholders and public administrations

[395] See more information at: https://3d.bk.tudelft.nl/projects/eunet4dbp/

[396] Germany is also developing prototypes solutions to integrate BIM into the official building application process using XPlanung and XBau systems.

[397] Olsson et al. (2019). Unbroken digital data flow in the built environment process – a case study in Sweden, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-2/W13, 1347–1352, https://doi.org/10.5194/isprs-archives-XLII-2-W13- 1347-2019.

[398] Olsson et al. (2018). Automation of Building Permission by Integration of BIM and Geospatial Data. ISPRS International Journal of GeoInformation, 7, 307.

[399] Smart Built Environment (2019). https://www.smartbuilt.se/in-english/

[400] Ciribini et al. (2016). Implementation of an interoperable process to optimise design and construction phases of a residential building: A BIM Pilot Project. Automation in Construction, 71, 62-73.

[401] E-ehitus (2019). Prototype of the BIM-based building permit procedure. https://eehitus.ee/timeline-post/bim-based-building-permit-procedure/

and to reduce information asymmetries[402]. Currently, building-related data, such as data of technical and construction information, building characteristics, energy-efficiency performance information and market transactions data, are limited and often inaccurate[403]. The lack of such data and a common repository where to store and display them altogether, generates additional costs and inefficiencies, stifles innovation, increases risk and undermines investors' confidence[404].

In this context, the EC has supported the development of digital building logbooks, notably through the elaboration of studies on the development of a European Union framework for digital building logbooks[405]. This focus on digital building logbooks is also confirmed in the new Circular Economy Action Plan and the Renovation Wave. The Action Plan refers to digital building logbooks as a means to promote circularity principles throughout the lifecycle of buildings; while the Renovation Wave states that the EC will introduce digital building logbooks that will integrate "*all building related data provided by the upcoming Building Renovation Passports, Smart Readiness Indicators, Level(s) and EPCs to ensure compatibility and integration of data throughout the renovation journey*"[406].

Box 23: What is a digital building logbook?[407]

In its study on the development of a European Union framework for digital building logbooks, the EC defines digital building logbooks as follows:

"*A digital building logbook is a common repository for all relevant building data. It facilitates transparency, trust, informed decision making and information sharing within the construction sector, among building owners and occupants, financial institutions and public authorities.*

A digital building logbook is a dynamic tool that allows a variety of data, information and documents to be recorded, accessed, enriched and organised under specific categories. It represents a record of major events and changes over a building's lifecycle, such as change of ownership, tenure or use, maintenance, refurbishment and other interventions. As such, it can include administrative documents, plans, description of the land, the building and its surrounding, technical systems, traceability and characteristics of construction materials, performance data such as operational energy use, indoor environmental quality, smart building potential and lifecycle emissions, as well as links to building ratings and certificates. As a result, it also enables circularity in the built environment.

Some types of data stored in the logbook have a more static nature while others, such as data coming from smart meters and intelligent devices, are dynamic and need to be automatically and regularly updated. A digital building logbook is a safe instrument giving control to users of their data and the access of third parties, respecting the fundamental right to protection of personal data. Data may be stored within the logbook and/or hosted in a different location to which the logbook acts as a gateway".

Source: EC (2020:12).

402 European Commission (2020), Definition of the digital building logbook Report 1 of the study on the development of a European Union framework for buildings' digital logbook, available at: https://op.europa.eu/en/publication-detail/-/publication/cacf9ee6-06ba-11eb-a511-01aa75ed71a1/language-en/format-PDF/source-164959934

403 Hartenberger et al. (2019) The Building Passport as an enabler for market transformation and circular economy within the built environment: SBE19 Conference Series paper and RICS (2017) Global Trends in Data Capture and Management in Real Estate and Construction

404 European Commission (2020), Definition of the digital building logbook Report 1 of the study on the development of a European Union framework for buildings' digital logbook, available at: https://op.europa.eu/en/publication-detail/-/publication/cacf9ee6-06ba-11eb-a511-01aa75ed71a1/language-en/format-PDF/source-164959934

405 See Reports 1 and 2 Report 1 of the study on the development of a European Union framework for digital building logbooks available at: https://op.europa.eu/en/publication-detail/-/publication/cacf9ee6-06ba-11eb-a511-01aa75ed71a1/language-en/format-PDF/source-180934421 and https://op.europa.eu/en/publication-detail/-/publication/58580f81-06b7-11eb-a511-01aa75ed71a1/language-en/format-PDF/source-180934421

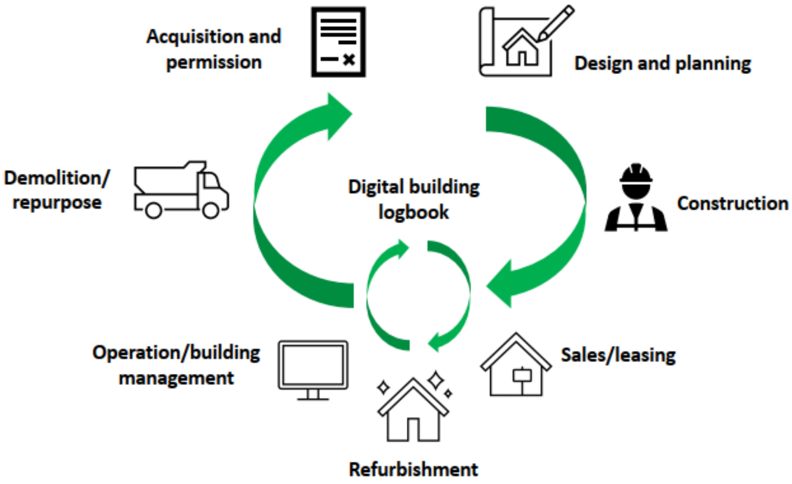
406 EC (2020:8). A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives. https://ec.europa.eu/energy/sites/ener/files/eu_renovation_wave_strategy.pdf

407 European Commission (2020), Definition of the digital building logbook Report 1 of the study on the development of a European Union framework for buildings' digital logbook, available at: https://op.europa.eu/en/publication-detail/-/publication/cacf9ee6-06ba-11eb-a511-01aa75ed71a1/language-en/format-PDF/source-164959934

Over the lifespan of buildings, data is routinely collected by multiple stakeholders for various reasons as many decisions rely on data availability. However, the lack of a common approach and structure among stakeholders which would make this wealth of information widely available, organised and easily accessible, makes this data often unusable as it gets discarded, forgotten or it is not compatible with other stakeholders' systems.[408] The lack of an overarching structure shared across the built environment leads to information asymmetry, lack of transparency and higher risk for investment and decisions.

Tools for information management applied to buildings have the potential to enable better decision making throughout the building's lifespan: management of technical and functional aspects, safety, conservation of economic value, certification[409], improved energy and environmental performances, etc. The organised and shared data that can be re-used, would not only reduce uncertainty, but also time and costs needed to recollect missing information, as shown in the figure below.

Figure 61: Building lifecycle



Source: EC (2020).

Functionalities of Building Logbooks

In the context of a recent EC study[410], an analysis of existing functionalities of digital building logbooks has been carried out. It shows that, existing building logbooks are both initiated by the public and private sector. However, they tend to differ in terms of approach: building logbooks initiated by the public sector are often mandatory and more likely to be paper based. On the other hand, the building logbooks driven by the private sector are often voluntary and are more likely to be digital.

In terms of their functionalities, the study shows that building logbooks are mainly used as collector of administrative and construction information together with operational maintenance and use. Therefore, currently logbooks act as a repository of administrative documents and/or data for maintenance and bureaucratic purposes, as well as to assess the buildings' energy performance. Few feature the more "advanced" functionalities (benchmarking with similar buildings, alerts on performance/condition, environmental impact, or compatibility with 3D/BIM models), which are offered by a reduced number of

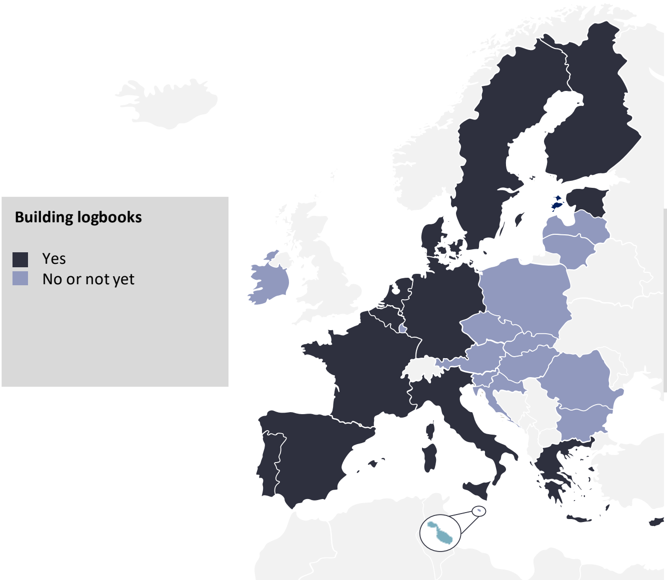
408 Rics (2017). Global trends in data capture and management in real estate and construction. https://www.rics.org/globalassets/rics-website/media/knowledge/research/insights/global-trends-in-data-capture-and-management-in-real-estate-and-construction-rics.pdf

409 Dejaco et al. (2017). Streamlined management of the built environment: the district and the building logbook as risk prevention tools. https://re.public.polimi.it/retrieve/handle/11311/1032396/227766/Building%20and%20urban%20logbook.pd f

410 European Commission (2020), Building logbook state of play, Report 2 of the study on the development of a European Union framework for buildings' digital logbook, available at: https://op.europa.eu/en/publication-detail/-/publication/58580f81-06b7-11eb-a511-01aa75ed71a1/language-en/format-PDF/source-search

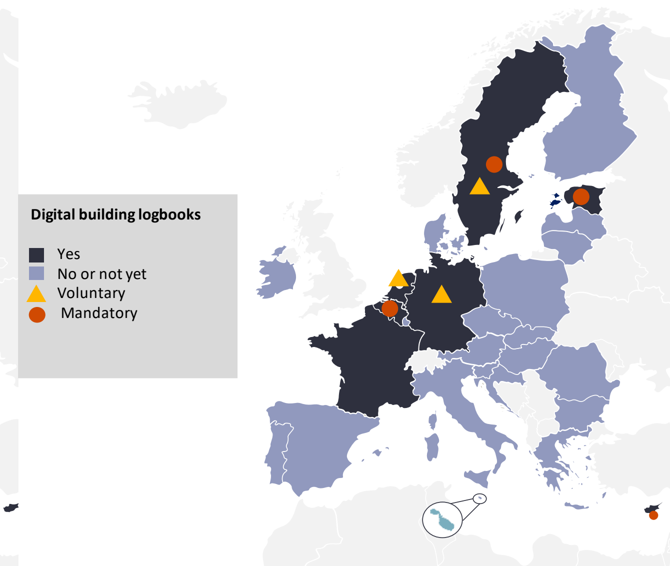
voluntary logbooks initiatives[411]. This is the case for instance of the Madaster[412], which facilitates registration, organisation, storage and exchange of data. It links the identity of materials to a location and registers this into a material passport. To do so, it is BIM/3D model compatible.

Figure 62: Mapping of existing building logbook initiatives (digital and paper-based)



Source: EC (2020)

Figure 63: Mapping of digital building logbooks



Source: EC (2020)

Digital building logbooks uptake in Europe has been increasing over the past few years, with 14 countries offering at least one. This trend is expected to continue in the near future with several EU Member States developing additional digital building logbooks. This will be supported by the commitment made under the Renovation Wave as mentioned in 3.1 EU policy framework and by the expected support under the Research and Innovation activities of Horizon Europe.

Digital building logbooks are hence expected to benefit from significant traction, which is partly explained by some of the key benefits they provide. These include trust, reliability, accountability; better decision-making; operation, use and maintenance; access to information; and the reduction of administrative burden[413]. Importantly, these benefits are relevant for all types of stakeholders, whether they are from the public or private sector. This is not to say that the development of digital building logbooks is a straightforward process, that is simple and does not require any efforts. In fact, the same study points out to several challenges digital building logbooks face, including the i) lack of motivation to update the contents; ii) unclear national legislation; iii) administrative burden for homeowners; iv) benefits not clearly identified and v) lack of consistency with other instruments.

All these initiatives share a common objective to increase data availability and transparency to a broad range of market players. The existing logbooks however differ in terms of focus (e.g. on energy efficiency or

411 EC (2020). Report 2 of the study on the development of a European Union framework for buildings' digital logbook. https://op.europa.eu/en/publication-detail/-/publication/58580f81-06b7-11eb-a511-01aa75ed71a1/language-en/format-PDF/source-164959934

412 See more information at: https://www.madaster.com/en

413 European Commission (2020), Definition of the digital building logbook Report 1 of the study on the development of a European Union framework for buildings' digital logbook, available at: https://op.europa.eu/en/publication-detail/-/publication/cacf9ee6-06ba-11eb-a511-01aa75ed71a1/language-en/format-PDF/source-164959934

materials), data handling and digital solutions employed[414]. Notably, paper-based logbooks do exist, although it is clear that only the digital version of logbooks allows to exploit all the functionalities and to ensure a proper availability of building data. The table below shows some of the existing and upcoming logbooks throughout EU countries.

Table 5: List of Building Logbooks currently in place or under development in the EU-27[415]

Building Logbooks under development							
Name	Country	Digital	Paper based	Mandatory	Energy efficiency purposes	Private	Building lifecycle phase
Building Passport by Green Building Council	Finland	√			√		Maintenance
Ilmastoviisaat Taloyhtiöt (Climate-Wise Housing Corporation)		√			√		Maintenance
Klimatdeklaration	Sweden	√			√		Maintenance
CB'23 (Circular Construction 2023)	Netherlands	√			√		Maintenance
PAS-E	Spain	√			√		Maintenance
Electronic building ID Code	Greece	√		√	√		Selling properties
SCI_BIM	Austria	√			√		Maintenance

Existing Logbooks							
Name	Country	Digital	Paper based	Mandatory	Energy efficiency purposes	Private	Building lifecycle phase
"Passeport Efficacité Énergétique"	France	√			√	√	Maintenance
BAZIMO		√			√	√	Maintenance
Be-In-Home		√			√	√	Maintenance
Homebook (experimentation)		√			√	√	Maintenance
IMMOBOX		√			√	√	Maintenance
Le carnet numérique du logement – Bureau Veritas		√			√	√	Maintenance
Le carnet numérique du logement – VILOGI		√			√	√	Maintenance
Wikihabitat		√			√	√	Maintenance
Mon logement numérique		√			√	√	Maintenance
BASTA loggbok	Sweden		√		√	√	Maintenance
Min Villa		√			√		Maintenance
Produktkollen		√					Maintenance
Bedrebolig	Denmark		√		√		Refurbishment
Dossier d'intervention ultérieure	Belgium		√	√			New construction

[414] European Commission (2020), Definition of the digital building logbook Report 1 of the study on the development of a European Union framework for buildings' digital logbook, available at: https://op.europa.eu/en/publication-detail/-/publication/cacf9ee6-06ba-11eb-a511-01aa75ed71a1/language-en/format-PDF/source-164959934

[415] This table is based on the survey, and additional desk research including the EC Study on the development of an EU framework for Digital Building Logbooks or the Moniteur (2020).

Existing Logbooks							
Name	Country	Digital	Paper based	Mandatory	Energy efficiency purposes	Private	Building lifecycle phase
Woningpas		√		√	√		Maintenance
Eigenheim Manager	Germany	√			√		Maintenance
Hausakte		√					Maintenance
Gëbaudepass		√					Maintenance
QDF Hausakte			√	√			New construction
Libro del Edificio	Spain		√	√			New construction – administrative purposes
Livro de obra	Portugal		√	√			New construction/ Refurbishment
Madaster	Netherlands	√				√	Maintenance
Opleverdossier			√				Maintenance
Fascicolo del Fabbricato	Italy		√	√			Refurbishment – public buildings only
Real estate service manual	Finland		√	√	√		Maintenance
Ehitisregister	Estonia	√		√			Design, Construction, Maintenance Renovation, Demolition
Energy Performance Certificate	Cyprus	√		√	√		Maintenance

Source: Adapted from EC (2020).

The mapping provided in the table above shows some clear trends that confirm that almost all the existing logbooks are mainly used for energy-efficiency purposes. This means that such logbook act as repositories of data and information to assess and monitor the energy profile of buildings, possibly even linked to energy efficiency certifications (BREEAM, LEED etc.). Many existing logbooks also collect data related to the construction of the building, in order to assess its quality and the materials used – like the Sweden's BASTA, that aims at avoiding the use of polluting and toxic materials. As a natural consequence, almost all logbooks focus on the maintenance phase of buildings, meaning that they collect data throughout the life of the building once it is finished and operating, which of course is the longest phase.

Finally, in terms of types of existing logbooks, 11 are digital while 10 are still paper-based and overall, 11 logbooks are mandatory[416]. Interestingly, the mandatory logbooks are often led by government and paper-based, suggesting that there is room for public intervention to exploit the full potentialities of digital logbooks. This is already the case of few Member States such as France (see box hereafter).

416 European Commission (2020), Definition of the digital building logbook Report 1 of the study on the development of a European Union framework for buildings' digital logbook, available at: https://op.europa.eu/en/publication-detail/-/publication/cacf9ee6-06ba-11eb-a511-01aa75ed71a1/language-en/format-PDF/source-164959934

Box 24: Introducing Digital Building Logbooks legislation - France[417]

In 2018, the "Evolution du Logement, de l'Aménagement et du Numérique" law 2018-1021 on the Evolution of Housing, Planning and the Digital Sector proposed the development of digital building logbooks. The objective was to provide a better understanding of the state of the buildings, their operational information and progressively improve their environmental performance.

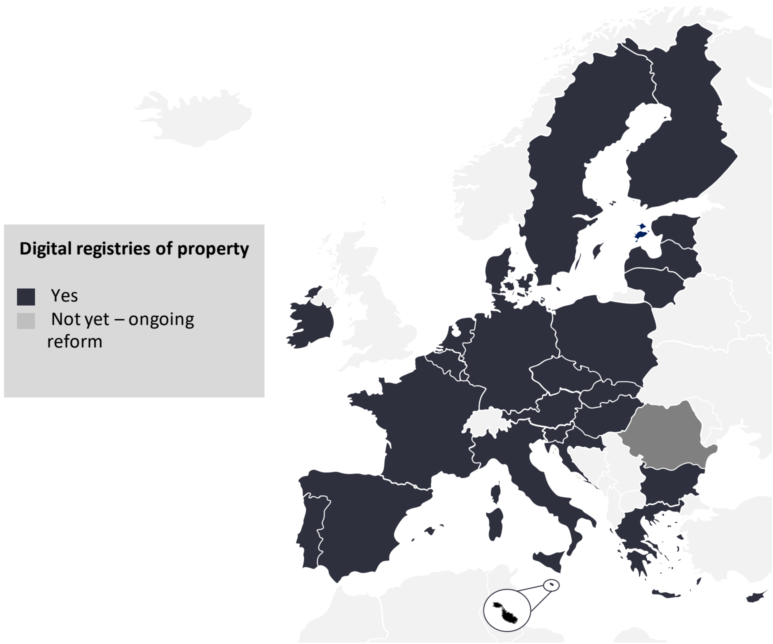
The building logbook should have been mandatory for all new buildings from January 2020 and for all existing buildings subject to ownership transfer as of January 2025. However, the implementation decree that was expected in December 2019 was never published. The "Conseil d'Etat", the French body in charge of advising the Government on legal matters, has issued a negative opinion on the draft decree with arguments including: the absence of a clear public interest that justifies a strong obligation which might be an infringement of liberties. This shows that the establishment is not simply and administrative process, and that it can face important challenges in its development.

The French Government is currently working on a new concept of the building logbook called "Carnet d'information du logement" which mainly focusses on the content of the building logbook and not on the digital format, which should be mandatory for all new buildings as of January 2022.

Source: EC (2020).

In addition to digital logbooks, EU Member States have developed digital registries of properties (cadastre), sometimes coupling it with Geographical Information System (GIS), as presented in the box below.

Figure 64: Digital registries in the European Union



Almost all EU countries have put in place a digital registry of properties. Only Romania is currently undertaking an IT project, with the support of the EC, to provide for the systematic digital registration of land and properties across much of rural Romania[418]. Existing digital registry initiatives are not particularly new.

Therefore, what differs is their level of sophistication. EU countries such as Belgium, France, Germany, Cyprus, Greece or Denmark have coupled their digital registry of properties to Geographical Information System - GIS. This technology is particularly useful for the representation and analysis of the city and the landscape, which are the context of the planned construction. In doing so, they can provide data on e.g. building (possibly segmented in generalised representations of its parts, such as walls and roofs) to wider pieces of lands (e.g., region, country or wider)[419].

While most of the GIS systems coupled with digital register of properties function in 2D, there are also cases such as Sweden, where 3D registration of properties has been conducted - thus moving from 2D to 3D mapping. In comparison to 2D, 3D maps depict objects in greater detail by representing the scale of real-

[417] European Commission (2020). Building logbook state of play. https://op.europa.eu/en/publication-detail/-/publication/58580f81-06b7-11eb-a511-01aa75ed71a1/language-en/format-PDF/source-search

[418] See more information at: https://ec.europa.eu/regional_policy/en/projects/Romania/digital-registration-of-land-and-property-in-rural-romania

[419] Janečka (2019). Transformation of 3D geospatial data into CityGML – a case of Prague. https://content.sciendo.com/view/journals/rgg/107/1/article-p41.xml?language=en

world objects. For instance, 3D maps can show systematically the height of a building or a hill and not just its location. This is particularly important in following the development of high-rise buildings and densification of built-up areas[420]. This is not without challenges. To move towards 3D, the cadastral jurisdiction must set up an adequate institutional and legislative framework to facilitate the registration of 3D parcels, and identify tools to collect the data[421]. In this regard, it is important to highlight the current development of the international standard ISO/AWI 19166 Geographic information – BIM to GIS conceptual mapping (B2GM). It defines the conceptual framework and mechanisms for the mapping of information elements from BIM to GIS to access the needed information based on specific user requirements[422].

In case where 3D maps are available, they can be coupled to BIM. In fact, according to our survey results, countries such as Sweden and the Netherlands are testing GIS and CAD (or BIM) for 3D visualisation environment[423]. 3D digital models such as BIM and 3D GIS could be utilised for accurate identification of property units, better representation of cadastral boundaries, and detailed visualisation of complex buildings[424].

3.3 Summary of the main findings

This section provided an overview of the pivotal role played by the public sector in supporting, incentivising, pushing for the uptake of digital technologies and processes in the construction sector. It does so through mainly three types of interventions: i) as policy-makers, being able to set the rules of the game and lead the digitalisation process; ii) as buyers and administrators of buildings and infrastructures, being able to influence the market, by providing business opportunities; and iii) as building-related public services administrators, hence having the possibility to digitalise their own processes first – so as to facilitate the digitalisation uptake down the value chains.

The first section demonstrated the interest of policymakers in supporting the digitalisation of the construction sector. At least 60% of the digitalisation strategies analysed touch upon the construction sector and some countries even opted for a vertical (and tailored) strategy for construction. These strategies often come accompanied by additional tools such as financial support in the form of grants, loans or equity; but also technical assistance types of support such as in the case of digitalisation construction platforms. While platforms do not always generate strong traction, they enable collaborations, synergies and knowledge sharing within the construction sector (which is an important aspect given its fragmentation); but also between the public and the private sector. In turn, this helps policy-makers design policies which are more likely to generate positive impact in the sector.

Secondly, governments can foster the adoption of digital technologies in construction projects by requiring their use in public procurement contracts. It has been shown that many governments have in place BIM requirements in their public procurement processes – or the plan to implement them in the near future. In addition, governments that did not opt for such mandatory requirements might have issued non mandatory requirements or standards regarding BIM in public procurement. Generally, feedback from both the industry and the public sector tends to indicate that this is an area that can be particularly beneficial to foster the digitalisation of the construction sector. However, it is important that in developing such

420 Sun et al. (2019). Utilizing BIM and GIS for Representation and Visualization of 3D Cadastre. https://www.researchgate.net/publication/337097476_Utilizing_BIM_and_GIS_for_Representation_and_Visualization_of_3D_Cadastre
421 FIG (2019). Best Practices 3D Cadastres. https://www.fig.net/resources/publications/figpub/pub72/Figpub72.pdf
422 FIG (2019). Best Practices 3D Cadastres. https://www.fig.net/resources/publications/figpub/pub72/Figpub72.pdf
423 Doner et al. (2020). 3D Digital Representation of Cadastral Data in Turkey—Apartments Case. https://www.mdpi.com/2073-445X/9/6/179
424 Sun et al. (2019). Utilizing BIM and GIS for Representation and Visualization of 3D Cadastre. https://www.researchgate.net/publication/337097476_Utilizing_BIM_and_GIS_for_Representation_and_Visualization_of_3D_Cadastre

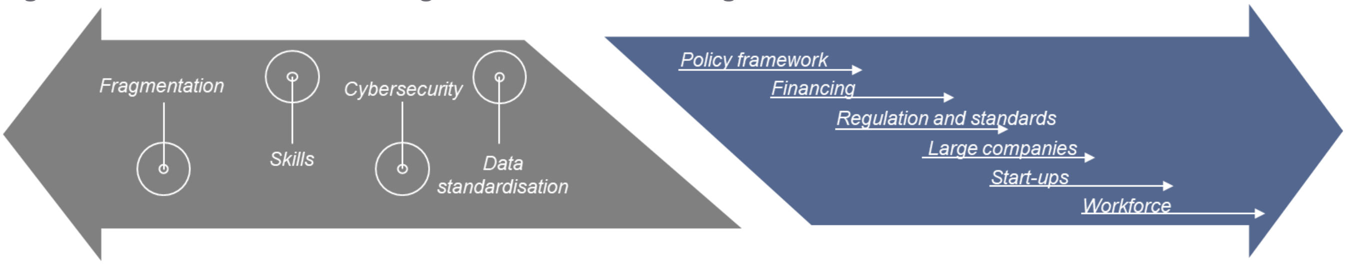
requirements, public sector actors may also need to i) build their BIM related capacities; and ii) balance their focus between low price and high quality.

Finally, governments also facilitate the uptake of digital technologies in the construction sector by providing e-services. In that sense, they are an indicator of the country's digitalisation and a direct interface between citizens and public administrations. When it comes to construction, national and local governments have a direct impact on public services related to the built environment, by e.g. issuing building permits and keeping the repository of building data and geospatial information (cadastre). These provide crucial information for the construction sector, and could facilitate their uptake of digital technologies. In this regard, an increasing number of EU Member States have adopted digital building permits systems and registries of properties. More than their growing spread, their level of sophistication is evolving as well, with the inclusion of GIS and 3D models for digital registry of properties for instance. Likewise, the uptake of digital building logbook has been increasing. The latter provides a unique point of information on buildings, collecting different types of data, which can then be leveraged by the public and private sector.

4.
Drivers and challenges of digitalisation in the construction sector

This chapter aims to provide an overview of the drivers and challenges relating to the digitalisation of the construction sector, as illustrated in the figure below.

Figure 65: Overview of the challenges and drivers for the digitalisation of the construction sector



4.1 Drivers

Two main tools were combined in order to identify the drivers for the digitalisation of the construction sector. First, desk research was conducted to collect secondary data on the different drivers and their characteristics, and whenever possible - their influence on the sector. The desk research included public institutions' reports, construction associations' studies and news articles, as well as statistical insights when available. In parallel, 15 semi-structured interviews were conducted with stakeholders (see 1.2 Methodology) with a view to i) identify additional drivers and get additional data on the identified ones; and ii) get a better understanding of the extent to which the identified drivers play a role in the integration of digital technologies in the sector.

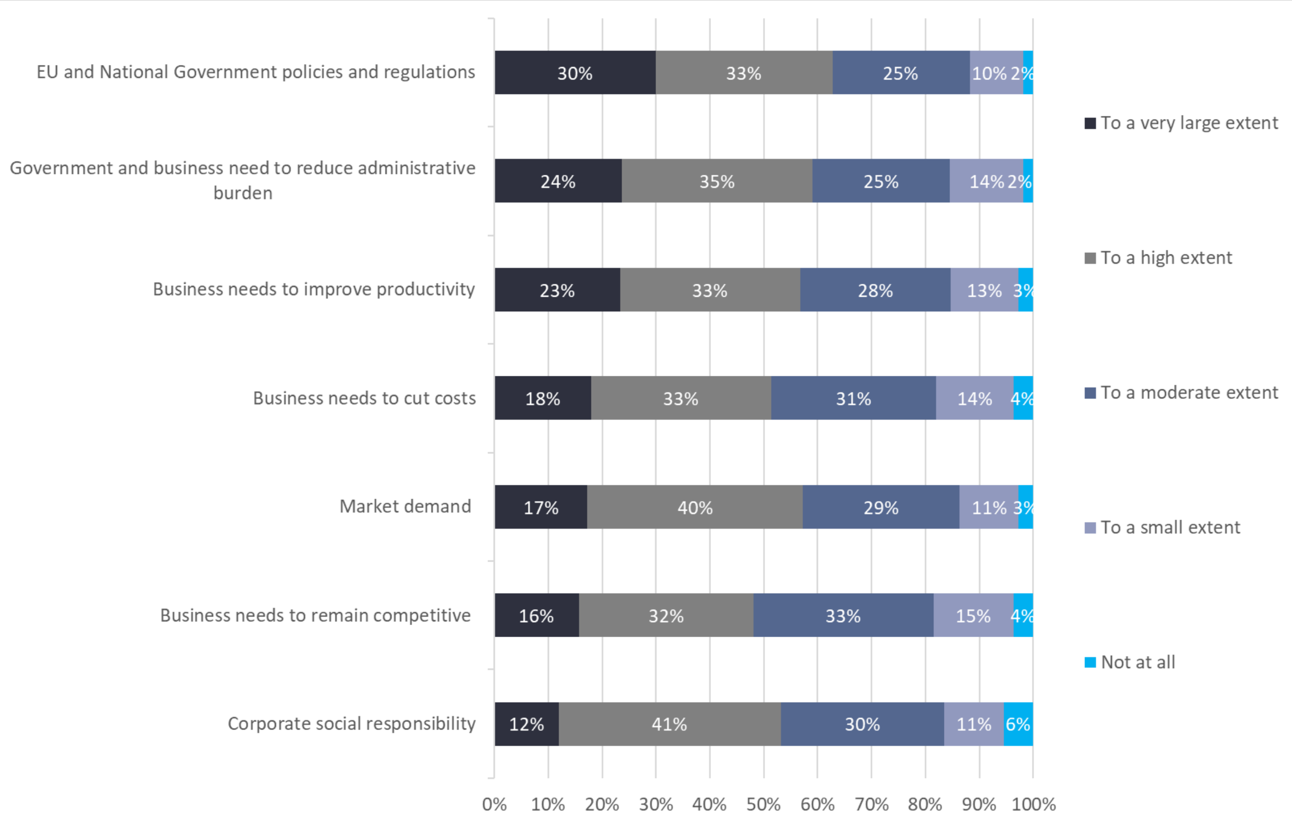
Following the desk research, a survey was developed to test these, by asking policy-makers, companies, associations and the academia to assess the extent to which they are important for the take up of digital technologies and tools in the construction sector. The results of the survey are hence presented at the European and national level, and in the case of the challenges - at the level of individual digital technologies. In the analysis of drivers we generally distinguish between two main types: those that relate to the development and implementation of government policies and are hence public sector-led; and those that relate to market development.

4.1.1 Overview of drivers at the EU and Member States levels

Both policy and market drivers play a key role in the digitalisation of the construction sector. With the exception of Corporate Social Responsibility, the survey respondents assessed that all drivers are important to a moderate or high extent for the take up of digital technologies and tools in the construction sector.

The figure below provides a more detailed overview of the importance granted by the stakeholders to each of the drivers. The percentage of stakeholders considering i) EU and national government policies and regulations, ii) government and business need for a better access to information and better decision making; and iii) business needs to cut costs as the most important drivers of the digitalisation of the construction sector exceeds 20%. In addition, EU and national government policy is the only driver deemed by over 60% of respondents as important to a high or very large extent. As we will see in the following more detailed analysis, this probably relates to the upcoming multiannual financial framework and the update or development of new EC policies that will shape the future of Europe.

Figure 66: Importance of drivers to take-up of digital technologies across EU



Source: ECSO survey, 2020

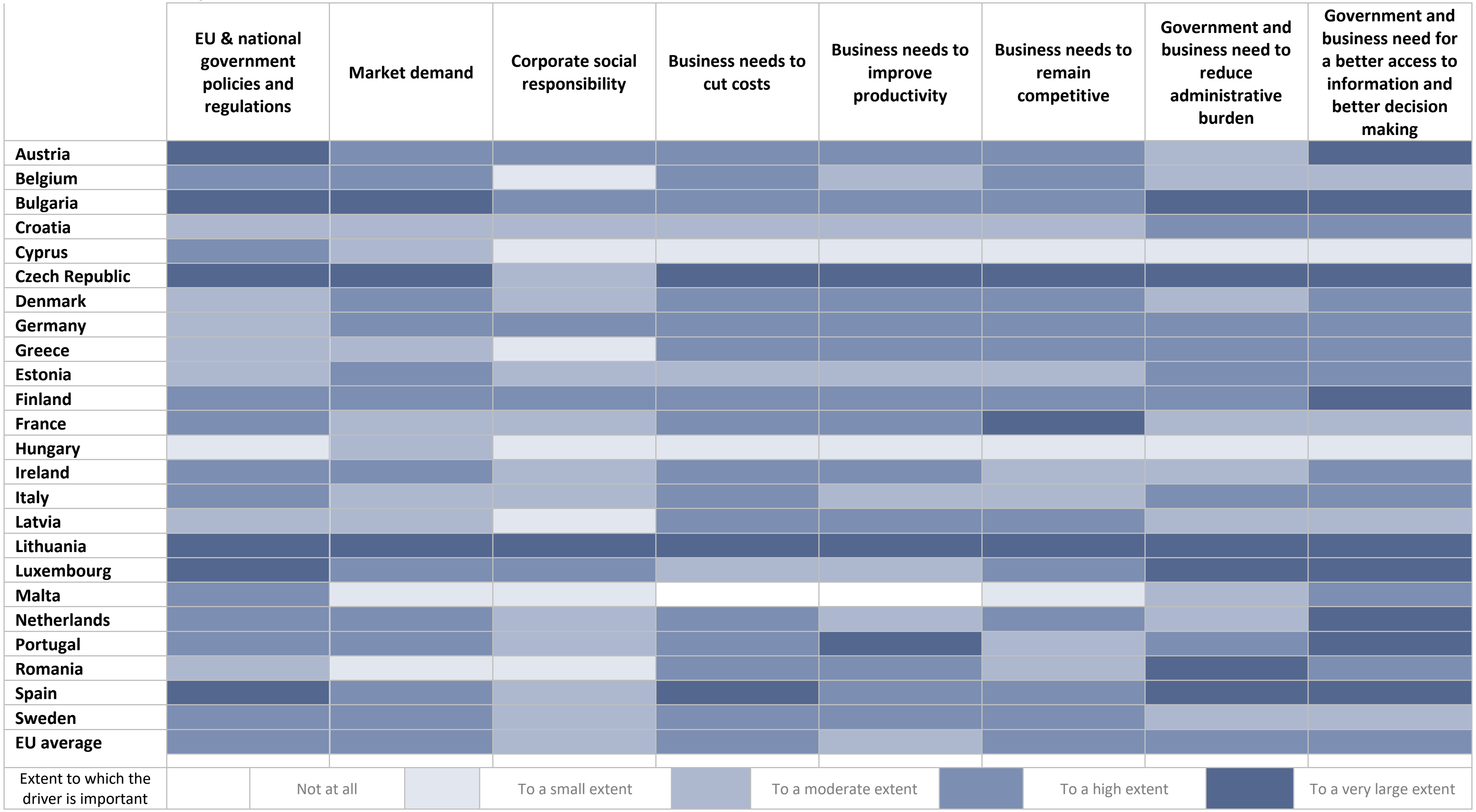
Market drivers are also important - such as companies needs to improve productivity, cut costs or even the importance of the market demand in the uptake of digital technologies in the construction sector. Between 50% to 57% of stakeholders consider these drivers as important to a high or very large extent. In a context where i) profit margins are generally getting tighter in Europe[425]; ii) the labour and skills shortages are increasingly felt in the sector; and iii) productivity has stagnated[426,427], construction companies are more and more aware that sectoral transformation needs to take place if the EU construction sector is to remain competitive in the mid to long-term. However, as seen in the figure above, it is interesting to notice that in terms of business drivers, corporate social responsibility – in line with the principles of circularity and sustainable development often promoted in public policies, is among the last drivers (12%) when it comes to driving to a very large extent the digitalisation of the construction sector. The table below reveals some of the differences between EU Member States, when it comes to determining the importance given to each driver.

[425] Deloitte (2018). European Construction Monitor 2017–2018: A looming new construction crisis? https://www2.deloitte.com/content/dam/Deloitte/pl/Documents/Reports/pl_European_Construction_Monitor_2017-2018.PDF

[426] McKinsey (2017). Reinventing construction. https://www.mckinsey.com/business-functions/operations/our-insights/reinventing-construction-through-a-productivity-revolution

[427] The Economist (2017). The construction industry's productivity problem https://www.economist.com/leaders/2017/08/17/the-construction-industrys-productivity-problem

Table 6: Drivers' importance in EU Member States



Source: ECSO survey, 2020

4.1.2 Policy drivers

This section will touch upon some of the key policy drivers identified. This includes EU and Member States' policies and regulations; governments' need to reduce administrative burden and to access information to develop evidence-based policies.

4.1.2.1 EU and Member States policies and regulations

EU and Member State policies and regulations are important drivers for the digitalisation of the construction sector. They are considered by most stakeholders as important to a high or very high extent. This is applicable for most EU countries, with respondents from Bulgaria, Spain, Lithuania and Luxembourg scoring this driver the highest in importance. This section provides additional details on the policies and regulations at EU and Member States level that play a role in the digitalisation of the construction sector or are expected to do so, touching upon various policy areas, such as energy efficiency, circular economy, innovation but also public procurement and data privacy.

Policies

Reflecting the increasing interest of citizens in sustainability, the EC has put in place ambitious policies to fight climate change and become the world's first climate-neutral continent by 2050. Of particular importance for the construction sector is the "Renovation Wave", which aims to foster building renovation to address climate change and support the recovery and the green and digital transition. More specifically, the EC aims to at least double renovation rates in the next ten years. This is expected to generate significant market opportunities for the construction sector and contribute to the creation of **160,000 green jobs**[428]. As mentioned in Chapter 3, digital technologies are expected to play a key role in this process.

The EU Clean package including the Directive on the Energy Performance of Buildings (2010/31/EU) – amended in 2018 (2018/844/EU) also promotes smart technologies and incentivises EU Member States to provide national financial measures to improve the energy efficiency of buildings. In this context, all EU Member States must develop a long-term renovation strategy[429] to support the renovation and decarbonisation of their building stock. In Europe, this would translate in the energy efficient renovation of **35 million buildings**[430].

The European Green Deal[431] also dedicates specific attention to the circularity of the construction sector, building on pre-existing policies and strategies[432]. As part of the new Circular Economy Action Plan, the EC intends to implement mandatory requirements on recycled plastic content and plastic waste reduction measures for key products such as construction materials. In doing so, the EC will stimulate the use of recycled materials, which has so far been developing slowly due to a lack of trust in recycled vs. new materials. With this requirement, the EC will therefore contribute to building the demand (and stimulate the offer of) recycled materials[433]. These policies provide the construction sector with additional market

428 European Commission (2020). A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1603122220757&uri=CELEX:52020DC0662

429 In this context, all EU Member States While so far 12 out of the 27 Member States have developed one, this number is expected to increase following the launch of the Renovation Wave. See more information at: BPIE (2020). A Review of EU Member States' Long-term Renovation Strategies.

430 Dr2 Consultant (2020). Renovation Wave: opportunities for the construction sector. https://dr2consultants.eu/renovation-wave-opportunities-for-the-construction-sector/

431 European Commission (2019). Building and renovating. https://ec.europa.eu/commission/presscorner/detail/en/fs_19_6725

432 Examples include the Waste Directive; the Construction & Demolition Waste Management Protocol, and more recently Circular Economy Action Plan and EU Industrial Policy.

433 European Environment Agency (2020). Greater circularity in the buildings sector can lead to major cuts in greenhouse gas emissions. https://www.eea.europa.eu/highlights/greater-circularity-in-the-buildings

opportunities, and offer other areas where digital technologies can help make a difference[434]. About **700,000 new jobs** could be created across the EU by 2030, if circular economy principles are applied across sectors[435].

The innovation and digitalisation policy framework has gained significant traction, including in the context of the next Programming Period. As elaborated in 3.1 EU policy framework, the EC has adopted several digitalisation policies and programmes, which will drive the uptake of digital technologies in the construction sector. It is worth noting that the approach to digitalisation is rather holistic: including the development of ICT infrastructure, the financing of research, development and innovation, but also technical assistance types of support (such as in the case of the DIHs). In doing so, it eliminates some of the constraints that construction companies face when adopting digital technologies, helping them shift their mindset and business routine/processes.

Overall, not only will these policies push the construction sector to do more, but to do differently, through the integration of new technologies and innovations. These will allow increasing energy efficiency and improve building quality (especially when it comes to renovation type of work). In turn, these new technologies and approaches require new knowledge and skills, particularly due the integration of new products, materials and processes.

Funding

In addition to policies, the EC provides a number of funding tools to finance the shift towards digitalisation. The new Multiannual Financial Framework places significant focus on the digitalisation of EU economies. In addition to dedicating **65% to 80%** of its total financing to a smart and green Europe, it includes two major programmes: Horizon Europe (budget of **EUR 95.5 billion**) and Digital Europe (total budget of **EUR 7.5 billion**). The investments will focus on digitalisation related infrastructure, the deployment of digital technologies, and research and innovation.

These programmes will be complemented by investment tools, including the Recovery and Resilience Facility (budget of EUR 672.5 billion), and InvestEU (budget of 31.6 billion). While there is still some uncertainty about the extent to which digitalisation investments will benefit the construction sector, it is important to note that the EU policies on e.g. smart cities, AI, SMEs digitalisation and circular economy tend to converge towards and/or involve, the construction sector. This will likely provide the construction sector with significant support for its digital transformation.

Regulation

As mentioned in the Chapter 3. Digitalisation policies and initiatives in the EU, developing an enabling regulatory framework that supports the uptake of digital technologies is also a key priority of the EU. In this regard, progress has been made relating to: i) data privacy and security; ii) public procurement; iii) circular economy and; iv) standardisation. These regulations are expected to lead to better access to information (for market players) and better decision making (for policymakers).

To foster the digitalisation of the construction sector, the EU started implementing a regulatory framework tackling issues relating to data privacy to allow data collection, exploitation, analysis and exchange. The most prominent examples include the General Data Protection Regulation (GDPR) - Regulation (EU) 2016/679, framing the exchange of data and helping clarify issues relating to data privacy. This is crucial for the construction sector and the use of digital technologies, such as IoT, sensors and digital

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434 Ratnasabapathy et al. (2019). A review of smart technology usage in construction and demolition waste management. http://dl.lib.mrt.ac.lk/handle/123/15237

435 European Commission (2020). Changing how we produce and consume: New Circular Economy Action Plan shows the way to a climate-neutral, competitive economy of empowered consumers. https://ec.europa.eu/commission/presscorner/detail/en/ip_20_420

building logbooks, which rely on data collection and sharing. When it comes to the use of drones, the EC also put in place the regulation on unmanned aircraft systems and on third-country operators of unmanned aircraft system (EU Regulations 2019/947 and 2019/945). Once again, it frames all related drone activities, with a view to protect citizens of potential abuse, but also to foster the uptake of this technology by European economies. More recently, the EC developed the Strategy for Data, which is expected to lead to the creation of the EU single market. The objective is to protect data sovereignty and to support EU economies' competitiveness.

As seen in Chapter 3.1.3 Regulations, BIM requirements are included more and more frequently in procurement processes, following the recommendation set in the 2014 EU Public Procurement Directive. Moving forward, the EC is expected to provide recommendations "*to promote Building Information Modelling in public procurement for construction and provide a methodology to public clients to conduct cost-benefit analysis for the use of BIM in public tenders*"[436]. Beyond BIM, green public procurement can also be used to favour construction companies that adopt digital and/or green technologies. As part of a broader stream towards sustainable public procurement, it can be expected that requirements focusing on digital, circular and/or green technologies (or processes) will be implemented in an increasing number of Member States.

While this approach "forces" construction companies to adopt digital technologies (requirement that may be replicated down the value chains), it provides financial incentives for companies, by providing them with a possible business opportunity – thus combining a carrot and stick approach. At the same time, it is important to note that such an approach works best when the final choice of the public authorities is not solely guided by the lowest price criterion.

The EC has been quite active in the area of standardisation. This includes the CEN BIM standards (more information in the section on the Policy drivers), but also DigiPLACE, which is an EU funded project. The latter is a framework allowing the development of future digital platforms as common ecosystems of digital services that will support innovation, commerce, etc: "*it will define a Reference Architecture Framework for digital construction platform based on an EU-wide consensus involving a large community of stakeholders, resulting in a strategic roadmap for successful implementation of this architecture*"[437].

4.1.2.2 Reducing administrative burden and fostering access to information

As explained in the previous chapters, the digitalisation of public services, such as digital permits systems, building logbooks and registries contributes to the facilitation of data collection, sharing, and analysis. This in turn contributes to i) reducing mistakes that can happen through the use of paper-based formats; ii) accelerating processes and reducing administrative burden; and iii) fostering the transparency of the public services delivered. As shown through the survey, stakeholders consider this dimension as being one of the most important drivers for the digitalisation of the construction sector. In 10 countries across the EU, stakeholders deem this dimension as the most important one.

Beyond these benefits, it is important to highlight that by providing digital information/processes to companies, governments are also incentivising the use of digital technologies for companies. At the same time, implementing digital processes and hence collecting digital data allows governments to exploit and

[436] European Commission (2020). A Renovation Wave for Europe. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1603122220757&uri=CELEX:52020DC0662

[437] CECE (2019). Introducing DigiPLACE, the Digital Platform framework for Construction in Europe. https://www.cece.eu/news/introducing-digiplace-the-digital-platform-for-construction-in-europe#:~:text=Introducing%20DigiPLACE%2C%20the%20Digital%20Platform%20framework%20for%20Construction%20in%20Europe&text=DigiPLACE%20is%20a%20framework%20allowing,support%20innovation%2C%20commerce%2C%20etc.

share these data, which can in turn feed into the design of updated or new government policies and regulations.

In this regard, the EC E-Government Action Plan 2016-2020[438] dedicated one of its three policy priorities to facilitating digital interaction between administrations and citizens/businesses for high-quality public services. This is based on the premise that high quality public services have a positive impact on business competitiveness; influence where investments are being made; and help lowering delivery costs[439] and increasing transparency. In particular, the Action Plan puts emphasis on the use of spatial data for urban, land-use and traffic planning, that can support innovations contributing to sustainable development. The focus of the EC on eGovernment & Digital Public Services is also reflected in the set-up of European interoperable platforms and the fostering of innovation through the Competitiveness and Innovation Programme (funding Large Scale Pilots and eParticipation projects).

These developments are relevant for construction companies in terms of accessing and using new (spatial) data to improve their services and processes. At the same time, digital public services would help lowering the costs and time that companies dedicate to e.g. submit applications to public institutions. While no data on the EU construction sector was found, it is estimated that in Europe, large companies (+2,000 employees) invest around 365 personnel days to submit both applications and data to governmental agencies[440].

4.1.3 Market drivers

This sub-section looks at the main drivers behind the digitalisation of the construction sector, from a market perspective. In doing so, it provides a better understanding of why construction firms start or keep investing in their digital transformation.

4.1.3.1 Improving productivity and cutting costs

The results of the survey show that one of the main drivers for the construction sector to digitalise refers to the business needs to cut costs and increase productivity. This is the case of a wide range of countries such as Spain, Portugal, Czech Republic, or Lithuania, which consider this driver as the most important in their country. However, among all construction companies, larger players are the ones who are most aware of the benefits of these digital technologies (e.g. cutting costs) and have the financial and human resource means to go through a digital transformation journey[441]. This sub-section hence looks more specifically at the role they play in contributing to the digitalisation of the construction sector.

As discussed in the previous section, large construction companies pave the way when it comes to the integration of digital technologies in business processes. These often work on large and complex projects, requiring strong coordination with several sub-contractors at tier 1 and sometimes tier 2 levels. They also demand a high level of efficiency (whether in terms of resources or energy) to ensure profit margins[442]. Beyond perceiving the potential benefits of digital technologies, large companies receive more and more client requests to implement digital technologies (such as BIM) in their projects. In other instances, implementing digital technologies may translate into offering additional services and products to clients,

[438] EC (2020). Accelerating the digital transformation of government. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016DC0179

[439] For instance, In Denmark, for example, electronic invoicing saves taxpayers €150 million and businesses €50 million a year. If introduced across the EU, annual savings could exceed €50 billion. See more information at: https://ec.europa.eu/digital-single-market/en/public-services-egovernment

[440] See more information at: https://theunitcompany.com/en/the-european-single-digital-market-egovernment-and-what-enterprise-architects-can-expect-part-2-3/

[441] ECSO (2019). Building Information Modelling in the EU construction sector. https://ec.europa.eu/docsroom/documents/34518/attachments/1/translations/en/renditions/native

[442] ECSO (2019). Building Information Modelling in the EU construction sector. https://ec.europa.eu/docsroom/documents/34518/attachments/1/translations/en/renditions/native

thus opening up new market opportunities. Therefore, if not for productivity, competitiveness and sustainability gains, large companies are incentivised to adopt digital technologies to seize further business opportunities. For example, as part of their work with public sector clients, large companies in some countries were incentivised to adopt BIM in order to be selected to implement a public procurement contract. This potential for exploiting further business opportunities partly explains why architects were one of the fastest growing groups to adopt BIM. They perceived BIM as "*an opportunity for architects to gain status and power*", since architects (who are trained on BIM) are increasingly contracted to act as BIM-coordinators in projects[443]. Finally, large companies have more capacity in terms of human and economic resources to implement digital technologies. **This does not mean that SMEs do not or cannot play a role in the uptake of digital technologies in the construction sector**. As described in the section 4.1.3.2 The role of start-ups in supporting digitalisation, SMEs and especially start-ups play a key role in the introduction of digital technologies in the construction sector, by tailoring them to the needs of construction actors.

Notably, SMEs – especially those from the traditional construction sector (e.g. in the operation and maintenance phase of the value chain), are often challenged in their digital transformation[444].

Exploiting the full benefits of digital technologies such as BIM requires all construction companies across the value chain to adopt the technology. Therefore, large companies tend to push BIM requirements to SMEs[445]. In that sense, large companies play a role in fostering the digitalisation of the construction sector. In some instances, large companies collaborate and support their counterparts implementing digital technologies – such cases were reported as relatively effective, and as a good entry point for SMEs to digitalise[446].

Investing in digital technologies to increase labour productivity is among the most important market drivers for the integration of digital technologies in the construction sector. First, increasing labour productivity helps mitigate the issue of labour shortages. Labour shortages are becoming more and more important in several EU Member States, as an important part of the construction force is going on retirement and will not be fully replaced. This driver is even more relevant in the broader context of the COVID-19 outbreak, and the underlying physical-distancing measures and restrictions on cross-border movement of labour. In this context, investing in digital innovation is often perceived as a way of mitigating the issue of labour (and skill) shortages[447].

4.1.3.2 The role of start-ups in supporting digitalisation

More and more attention is paid to construction start-ups or the so-called "construction tech" as a means of driving digitalisation in the construction sector. Construction start-ups fill up a gap by pursuing opportunities associated with radical innovations[448], and translate it in a way that makes financial and technical sense in the construction sector[449]. These start-ups provide focused solutions around a single technology, solving specific but sector applicable issues, mainly around BIM, additive manufacturing and

443 Davies et al. (2015). BIM in Europe: innovation networks in the construction sectors of Sweden, France and the UK. http://centaur.reading.ac.uk/67468/

444 CECE (2019). Digitalisation in the construction sector.

445 Vidalakis et al. (2016). BIM adoption and implementation: Focusing on SMEs. https://radar.brookes.ac.uk/radar/file/72629d82-db78-44ab-8b94-31efa7b20819/1/BIM%20adoption%20and%20implementation%20in%20SMEs%20-%202019%20-%20Vidalakis%20Abanda%20Oti.pdf

446 CECE (2019). Digitalising the construction sector. https://www.cece.eu/stream/digitalising-the-construction-sector-unlocking-the-potential-of-data-with-a-value-chain-approach

447 See more information at: https://www.procore.com/jobsite/construction-turns-to-tech-to-ease-labor-shortage/

448 JRC (2017). Building Information Modelling (BIM) standardization. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC109656/bim.standardization_1.pdf

449 Amstreiter (2020). Tech startups are key to fixing construction's productivity problem. https://www.verdict.co.uk/construction-startups-productivity/

drones[450]. These issues relate to activities such as Environmental Engineering/Services, Specialty Trade Contractors, and activities related to Building Materials and Construction Machinery[451].

As a result, Venture Capital (VC) funding in construction start-ups increased globally in the past few years, going from EUR 43 million in 2012 to EUR 1,199 million in 2018 (with a record increase of 177% between 2017 and 2018)[452]. However, VC investments are largely concentrated in the US and China, with the European digital start-ups accounting for only 4% of global VC funding in digital construction start-ups in 2017. France, Germany, and Sweden attract most of these investments.

Several reasons help explain why construction tech are playing an increasing role in spreading digital technologies. First, they develop specific solutions which can be integrated in companies' IT systems, rather than seeking to digitalise an entire organisation's IT infrastructure. In doing so, they are able to tailor the solution to the buying company and lessen the entry cost of construction companies desiring to digitalise. Second, start-ups typically monetise by offering digital transformation as an operational expense rather than a capital expense. In other words, this means that construction companies pay a subscription to start-ups to use their services (see example in the box below). This is particularly relevant in times when the construction sector profit margins are relatively low which limits their capacity to invest substantially in digital technologies[453].

Box 25: Five examples of construction digital start-ups

Klarx launched an online platform for renting construction equipment in 2015 and since then, customers like Strabag, Max Bögl and Deutsche Bahn have been able to find the machine they are looking for in just a few clicks. With over 200,000 machines available, Klarx enables building projects to be planned in a more predictable, faster and cost-efficient manner. In 2018 they raised €4 million and just raised another round of €12.5 million, positioning themselves as pioneers in the digitalisation of construction machinery rental.

Vizcab, founded in 2020, allows construction and real estate players to reduce their carbon footprint, with the help of data calculating, reporting and visualisation tools. It has three main tools: The Vizcab Explo tool (which allows project owners and their advisers to build secure and competitive carbon energy strategies); The Vizcab Eval (an LCA calculation software used by engineering and general contractors to optimise and validate the achievement of "regulatory" carbon levels), and the Vizcab Dashboard (capitalisation and reporting platform). French construction tech startup Vizcab has announced closing its first funding round of €1.6 million, with the support of Banque des Territoires and A / O Proptech, as well as the Unibail-Rodamco-Westfield group.

Qualis Flow is a cloud-based software for monitoring and forecasting environmental risk in construction. The London-based start-up helps contractors to track, monitor and predict the environmental risks of their projects, and thus reduce their overall carbon footprint. In addition, its features enable compliance, automated reporting and optimisation of decision making. In June 2019, the start-up raised €800k seed to further develop its platform and attract more customers like their early adopter, Canary Wharf Contractors.

Spacemaker is an Oslo-based start-up whose mission is to design better cities with AI. Its technology helps city planners, real estate developers, and architects to maximise the potential of a building site by allowing them to explore and generate a multitude of site proposals and choose the best ones. Spacemaker combines expertise from a wide range of fields including architecture, mathematics, physics, and machine learning to provide users with creative, high-quality site proposals so that municipalities and developers can build more efficiently and densely to accommodate the world's rapidly growing cities. Founded in 2016, Spacemaker has offices in Oslo, Stockholm, Barcelona and Boston, and recently raised a EUR 22 million Series A round to accelerate the company's roll out, further develop its product and grow its engineering and commercial teams.

XYZ Reality is a construction tech start-up based in London providing an augmented reality solution. Founded in

450 Deloitte (2019). Point of View on Digital Construction. https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/energy-resources/deloitte-nl-eri-point-of-view-digital-construction.pdf

451 JRC (2017). Building Information Modelling (BIM) standardization. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC109656/bim.standardization_1.pdf

452 Deloitte (2019). Point of View on Digital Construction.

453 Amstreiter (2020). Tech startups are key to fixing construction's productivity problem.

2017, XYZ Reality offers to transform the way people work in construction by delivering a 3D view of a site, which, along with augmented reality technology, promises to construction costs by 20% and speed up project tasks by up to 69%.

BuildSafe is a Stockholm-based company that provides a safety management cloud service for the construction sector. The tool helps construction companies and builders with reporting, documenting and monitoring risks in construction projects and at the same time reduces unnecessary paperwork. Founded in 2015, Buildsafe already has some major clients such as Skanska and Fabege and €1 million in funding to bring more transparency in the sector.

Source: EU Startups, 2019[454].

However, the role construction start-ups play is not without challenges and risks as further explained in the challenge section.

4.1.3.3 Other construction sector trends

While it is still too early to provide an assessment of the impact of the COVID-19 outbreak, the construction sector was[455] and is expected to be significantly affected. In fact, a recent survey[456] conducted by an EU construction association shows that 62% of construction sites have been significantly affected or even closed throughout Q1 2020– causing productivity loss, delays and additional costs. In addition, construction investment declined following the likely slump in the number of building permits, administrative bottlenecks for processing such permits and the likely absenteeism of the employees[457]. As explained by one stakeholder interviewed for this study, while contracts that are already signed are expected to be completed (thus maintaining a certain level of activities), new contracts are still uncertain.

Following the COVID-19 outbreak, it is becoming ever more apparent that digital technologies will play an increasing role in what will be the recovery but also the new normal of the sector. As highlighted in a recent study, this new normal is an opportunity for disruption and growth[458]. In fact, during the COVID-19 outbreak, the construction sector partly shifted towards remote ways of working: architects and engineers rely to a larger extent on BIM 4D and 5D to re-plan projects and adapt schedules. In addition, Digital Twin solutions are also increasingly used from start to end of the construction project[459]. In the longer-term, trends such as offsite construction are also expected to pick up, following the need to build in controlled environments (which is even more important in a world that requires close management of the movement and interaction of workforces). A recent study confirmed this finding – adding that over 50% of survey respondents (global construction companies decision makers) have already raised investment notably in digitalisation and supply-chain control[460].

This view was shared by some of the private sector stakeholders interviewed for this study, who perceive the COVID-19 outbreak as a major incentive to do things differently, relying more on digital technologies in order to survive and hopefully strive in the future. This indicates that already soon digitalisation may become not

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[454] EU Startups (2019). 10 European startups shaping the future of the construction industry. https://www.eu-startups.com/2019/09/10-european-startups-shaping-the-future-of-the-construction-sector/

[455] See more information at: https://www.ebc-construction.eu/2020/06/05/updates-on-covid19/#impact

[456] FIEC and CECE (2020). 2020 - May construction Europe fiec-cece joint article covid19. https://www.fiec.eu/covid-19-corner/construction-europe-fiec-cece-joint-article-covid19

[457] EC (2020). European Economic Forecast. May 2020.

[458] McKinsey (2020). How construction can emerge stronger after coronavirus. https://www.mckinsey.com/business-functions/operations/our-insights/how-construction-can-emerge-stronger-after-coronavirus; WEF (2020). Here's how smart construction could transform home-building after COVID-19. https://www.weforum.org/agenda/2020/08/here-s-how-smart-construction-could-transform-home-building-after-covid-19/

[459] McKinsey (2020). How construction can emerge stronger after coronavirus. https://www.mckinsey.com/business-functions/operations/our-insights/how-construction-can-emerge-stronger-after-coronavirus

[460] McKinsey (2020). The next normal in construction. https://www.mckinsey.com/~/media/McKinsey/Industries/Capital%20Projects%20and%20Infrastructure/Our%20Insights/The%20next%20normal%20in%20construction/executive-summary_the-next-normal-in-construction.pdf

so much an option but a requirement that would allow companies to remain agile[461], competitive and secure a profit margin. In this context, a recent study[462] cited three technologies as potential game changers for the sector. The first is IoT, which will allow for the emergence of new business models, such as performance-based and collaborative contracting. Second, BIM (including its dimensions on time and costs) and Digital Twins will help address risks upfront and hence the sequence of decision making in construction projects. In doing so, it puts traditional construction processes (from engineering to the operation) into question. Last, automated parametric design is expected to transform engineering by improving on-site collaboration.

In parallel, as explained earlier, an important part of the construction workforce is expected to retire in EU countries such as Sweden[463] or Finland[464]. Provided that the sector succeeds in attracting young workers, a shift of generation (and mindset) could take place. In fact, new professionals in the construction sector are more interested in digital technologies. For instance, a survey in the UK construction sector reveals that "*the next generation of civil engineers appear to have more faith in the power of technology than their senior leaders. Nearly 60% of younger civil engineers believe technology is a key solution to the skills problem, only 23% of the old generation agree*"[465]. This shift in generation may facilitate the move of the construction sector towards digitalisation.

For instance, architects applying e.g. generative design tools, need to learn technical skills, but also design in new ways. In this regard, a recent study[466] highlights the need for architects to equip themselves with new technical skills, such as the ability to build standard libraries of design elements and automate certain parts of the design process (thus acquiring "developer" type of skills). Besides technical skills, it is also about developing the capacity to adopt new digital ways of working, moving away from linear to iterative processes in short test-and-refine loops (especially when reviewing and refining generative designs).

461 Roland Berger (2020). What the new normal could look like in construction. https://www.rolandberger.com/en/Insights/Publications/What-the-new-normal-could-look-like-in-construction.html
462 McKinsey (2020). The next normal in construction. https://www.mckinsey.com/~/media/McKinsey/Industries/Capital%20Projects%20and%20Infrastructure/Our%20Insights/The%20next%20normal%20in%20construction/executive-summary_the-next-normal-in-construction.pdf
463 ECSO (2020). Country Fact Sheet Sweden.
464 ECSO (2020). Country Fact Sheet Finland.
465 See more information at: https://info.vercator.com/blog/how-to-solve-the-skills-shortage-in-construction-innovation-automation-and-point-clouds
466 McKinsey (2019). Decoding digital transformation in construction.

4.2 Challenges

Digitalisation is associated with better firm and project performance. Firms leveraging on digital technologies tend to have higher productivity and better management practices than non-digitalised firms, and construction projects involving digital tools tend to have a lesser incidence of delays, additional costs and errors. However, European construction firms are still less digitalised than their American counterparts and generally lag behind companies in the other sectors[467].

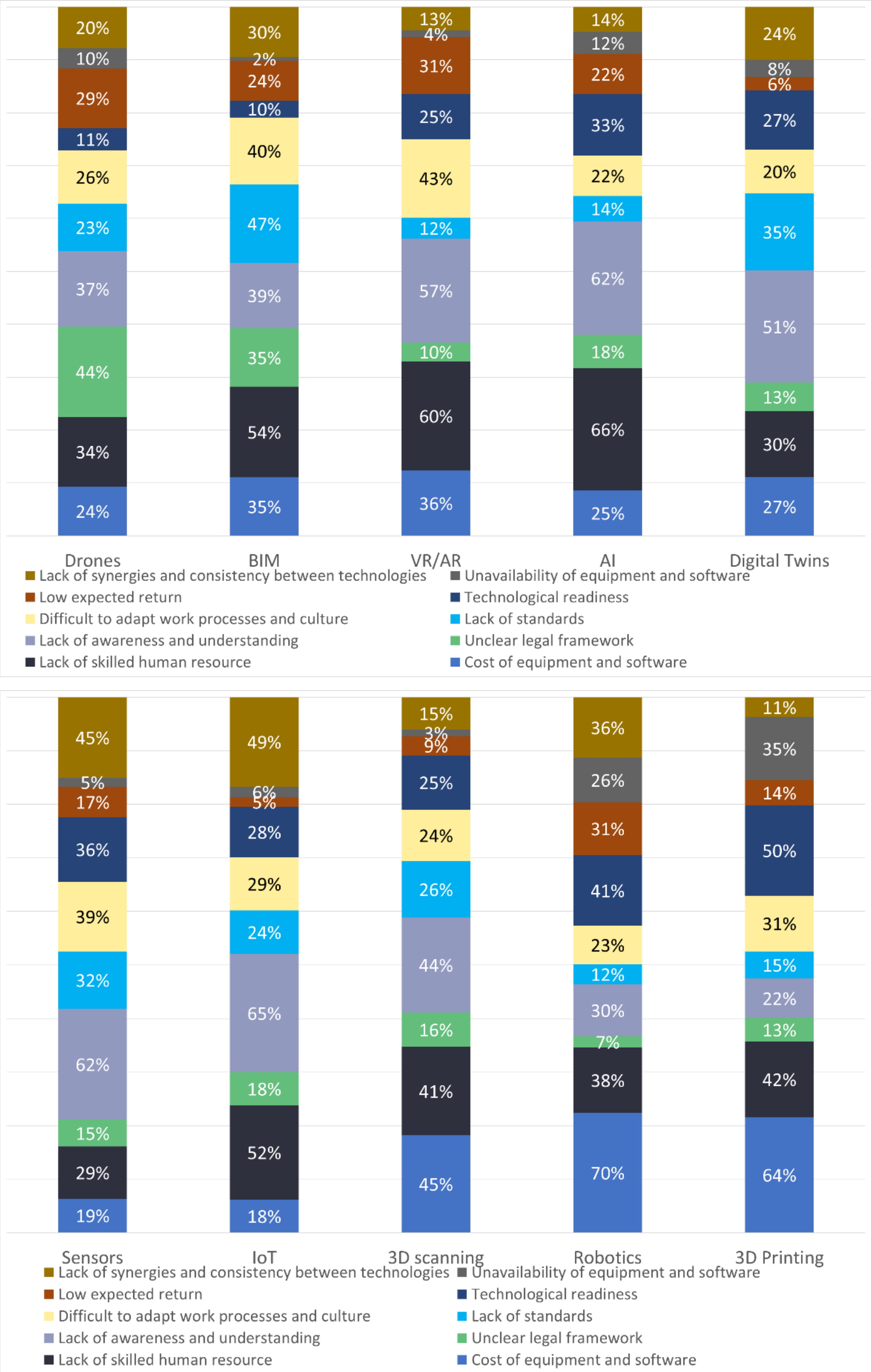
This part of the report provides an analysis of the main factors that shape and influence the adoption of digital technologies in the European construction sector. More specifically, the report analyses the barriers linked to the fragmentation of the construction sector and of its value chain, the shortage of qualified workers, concerns related to cybersecurity and to the business perspective, and issues of standardisation of data and methods. In doing so, this part of the report underlines a set of insights that should be considered for policies to reach their desired effects in practice.

These challenges were identified throughout desk research and with the input from sector stakeholders, and then tested through an online survey sent to private construction companies, industry organisations, and public authorities. Although the extent to which each challenge affects the construction sector is different, from Figure 67 it is possible to see that the **cost of equipment and software, lack of skilled workforce, and lack of awareness and understanding are the three main factors hindering a faster and broader digitalisation of the European construction sector**. That being said, the results from the survey showed that significant variations are present. For example, the cost of equipment is an important limiting factor for 3D printing and robotics, but it is a secondary issue for the adoption of sensors. On the other hand, lack of skilled workforce particularly affects the adoption of Artificial Intelligence and Virtual and Augmented Reality, and limits only to a lesser extent the use of sensors.

The Figure below provides an overview of the relevance of each challenge per each technology based on the results from the ECSO survey. Each respondent had the possibility to indicate multiple challenges for each technology, as more than one challenge can limit the development and adoption of a digital technology. For this reason, the total per columns is higher 100, as each percentage should be read as the share of respondents that indicated that specific challenge as relevant for that specific technology, and should not be read as the relative weight of each challenge in relation to the others.

[467] EIB, Who is prepared for the new Digital Age? Evidence from the EIB Investment Survey.

Figure 67: Relevance of challenges per each technology (EU weighted average)[468]

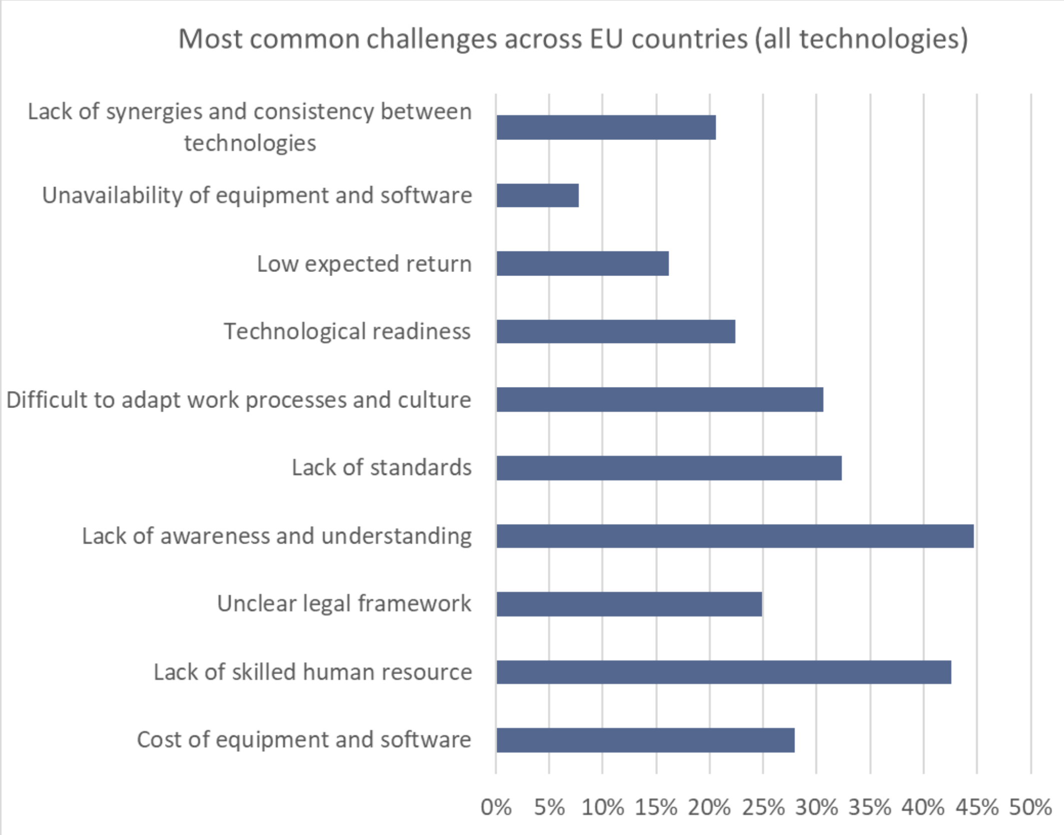


Source: ECSO survey

468 Based on survey results. Respondents had the possibility to select more than one option; hence, numbers per row and per technology do not add up to 100 but it reflects the percentage of respondents that selected each challenge in each technology. ECSO survey results are not statistically representative and should be interpreted accordingly.

Overall, Figure 67 shows that the general lack of awareness about digital technologies in the construction sector, and the lack of skilled workforce are the two main barriers identified by respondents to the survey.

Figure 68: Percentage of total respondents to the survey that considers each challenge as relevant



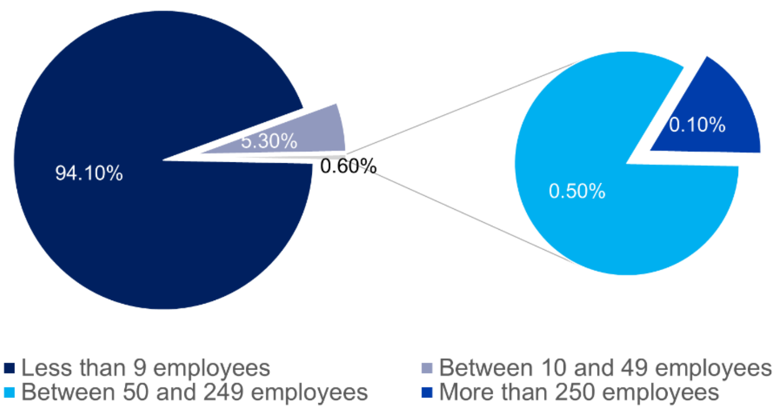
Source: ECSO survey

Nonetheless, by looking at the results of the survey at country level (see Table 7 in Annex 6: Relevance of challenges by country) it is possible to see that most challenges are at least somewhat relevant in all Member States and some common trends can be analysed. The technological readiness and the low expected returns of digital technologies in the construction sector are generally assessed as less relevant issues compared to the rest. The latter suggests that respondents acknowledged the added value of digitalisation in construction activities. Lack of skilled human resource and lack of awareness and understanding are the two challenges affecting the most the digitalisation of the construction sector, followed by the cost of digital technologies.

4.2.1 Fragmentation of the construction sector

The European construction sector is characterised by a high degree of fragmentation, being composed by numerous companies often specialised in very specific kind of activities, thus requiring the involvement of multiple actors throughout the different phases of a building lifecycle[469].

Figure 69: European construction sector per company's size



Source: Adapted from European Builders Confederation's data.

In addition to this, more than 99% of the companies involved in the construction sector are SMEs. Of these, 94.1% are micro enterprises with 9 or less employees[470,471], 5.3 % have 10 to 49 employees, 0.5% have 50 to 249 employees, and only 0.1% of the European construction companies have 250 or more employees, hence being classified as a large enterprise[472].

When it comes to **investment in digital tools in Europe**, only 30% of companies with less than 10 employees invested in new technologies, against 79% of companies with more than 250 employees[473]. This is explained by several interrelated factors:

1. **Low levels of investment**. The construction sector generally invests little in innovation, with only 24% of the construction companies investing in new products, processes or services[474]. The sector is traditionally the sector with the lowest share of investments aimed at expanding the company's capacities, and with one of the highest shares of investment to maintain the current capacity[475]. In addition to that, the profit margins of the construction sector have been tightening over the past few years, leaving little room for manoeuvre to finance investments – especially in digital innovation. This trend is likely to be reinforced by the COVID-19 pandemic economic impact on the sector, and this can already be partially seen in the fact that more than 40% of European construction companies foresees to reduce its levels of investment compared to the previous financial years, with only 25% expecting to increase them[476].
2. **SMEs characteristics**. A recent report reveals that construction SMEs faces several challenges such as "*difficulty of envisioning the potential digitised futures of their business, low digital maturity-level of the employees and the employers, and most importantly, the inherently limited human-resources*"[477]. This shows that, construction SMEs interested in digital technologies would need support in understanding which digital technology would best fit for their objectives. In addition to that, once the digital technology selected, construction SMEs have **limited human and financial**

469 Nawi, M.N.; Baluch, N.; Bahauddin, A.Y. Impact of Fragmentation Issue in Construction Industry: An Overview.
470 EC, Supporting the digitalisation of the construction sector.
471 European Builders Confederation, members data. www.ebc-construction.eu
472 Ibidem.
473 Ibidem.
474 EIB Investment Survey 2019.
475 European Builders Confederation.
476 EIB Investment Survey 2020.
477 European Commission (2019). Supporting digitalisation of the construction sector and SMEs. https://ec.europa.eu/docsroom/documents/38281

resources[478], which are required to: i) buy the software/tool; ii) train employees; and iii) adapt their processes and routines to this digital technology. While one could argue that financial resources can be obtained externally through loans from banks, it is important to highlight that **43% of construction companies identified access to finance as a long-term barrier to investment**, thus making the costs of digital tools a main bottleneck for SMEs. Likewise, SMEs prefer not to externalise human resources (as a result of externalising specific services) so as to avoid losing their independence to a third party[479].

3. **Low awareness of the benefits**. Using digital tools often requires an upfront investment from companies, as they need to buy the necessary equipment, purchase the software and upskill their employees. This initial investment is in theory compensated, and surpassed, by the efficiency gains and, more generally, by the added value that digitalisation brings. However, **the benefits provided by digital technologies are often not clear**[480]. This is particularly the case of SMEs, which tend to work mainly on smaller projects, either independently or as subcontractors, where the efficiency gains are more limited. Indeed, "lack of awareness and understanding" is a main bottleneck for most of the technologies, including Sensors, IoT, VR/AR, AI, and Digital Twins, together with "cost of equipment and software", which is of particular relevance when it comes to investments in 3D Printing and Robotics, according to the survey (see Figure 67: Relevance of challenges per each technology (EU weighted average)above). As a result, many fear that the adoption of digital tools would not provide sufficient benefits to justify the initial investment required. Aware of this issue, national governments are increasingly providing support to incentivise construction SMEs to invest in digital technologies. This support may take the form of fiscal incentive, but also technical assistance (for more information, refer to 4.1.2 Policy drivers).

Box 26: The cost of BIM software

BIM software can be an important barrier for SMEs, as the upfront cost is often not corresponded by rapid and / or certain RoIs.

The price of BIM software varies considerably depending on the software chosen, on its functionalities and on the size of the company. A basic program's license can be purchased for thousands of euro per year (between EUR 6,000 and EUR 7,000); however, for a complete and more professional version, the company might need to spend **more than EUR 30,000**[481] **per year in software licence**. To this, the cost of training should be added, which varies considerably from country to country.

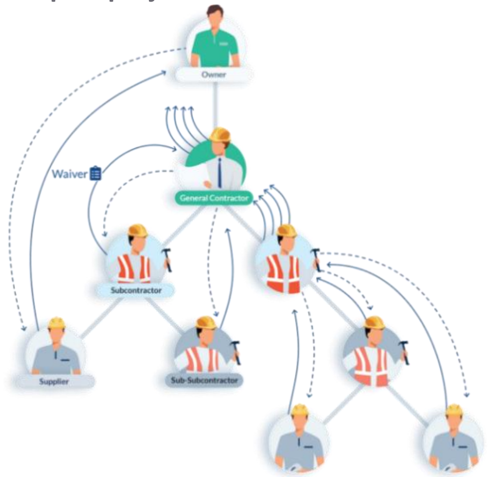
Indeed, the cost of personnel trained to work with BIM, the cost of computer to run BIM software, and subscription to cloud storage all add up to the price of BIM software per se. These costs vary significantly from country to country, but still represent an importance element to consider for companies interested in investing in BIM.

The fragmentation of the sector is also reflected in the implementation of construction projects. Often, few large-scale companies engaged in heavy construction (e.g. civil and industrial construction work) manage the construction project, while a number of smaller companies specialised in trades such as electrical and plumbing work act as subcontractors, thus working only on a very specific part of the construction[482].

[478] EIB, Who is prepared for the Digital Age?
[479] CECE (2020). Digitalising the Construction Sector. https://www.cece.eu/stream/digitalising-the-construction-sector-unlocking-the-potential-of-data-with-a-value-chain-approach
[480] CECE (2019), Digitalising the Construction Sector. Unlocking the potential of data with a value chain approach.
[481] Guida Edilizia, Quali sono i software con tecnologia BIM e i loro prezzi? https://www.guidaedilizia.it/bim/quali-sono-i-software-i-loro-prezzi/
[482] CRESME, Le Resistenze delle Costruzioni all'aumento della produttività e all'innovazione. http://www.cresme.it/it/articoli/23/le-resistenze-delle-costruzioni-allaumento-della-produttivita-e-allinnovazione.aspx#

Because of this, stakeholders interviewed for the scope of this report stated that implementing some digital technologies is challenging. For the case of BIM its implementation would require most if not all actors involved to use it, which is an important barrier for large projects with numerous companies involved[483].

Figure 70: Construction supply chain for complex projects[484]



Source: Levelset, 2020.

In addition to fragmentation among the actors involved, digital technologies are not equally spread and adopted in each of the different phases of the construction value chain. For instance, certain digital technologies such as BIM referring to the design and engineering phase seem to be raising interests and traction among construction actors like architects and engineering consultancies. This is explained by the fact that i) the benefits from the use of BIM are more tangible for this specific part of the value chains; ii) construction companies can leverage on BIM to offer new services and exploit market opportunities. However, the situation may differ for companies in the construction phase of the value chain, which may not perceive the same benefits and are hence less interested in adopting digital technologies[485]. Importantly, not utilising digital tools in the design phase might limit construction companies from using them in the next phases, as it would require additional work and investments to digitalise the project. In turn, it is less likely that the renovation of a buildings leverages on digital technologies if these have not been used nor integrated during the previous phases. This issue was also confirmed by the results of the survey, where "lack of synergies and consistency" was selected as one of the most relevant challenges for the construction sector (see Figure 67 at the beginning of the section).

In addition, fostering coordination among professionals across the different construction phases is crucial to incentivise all construction companies down the value chains to implement digital solutions[486]. Currently, there is often a lack of collaboration between the professionals involved in a construction project, even in the same phase. The design and construction phases are sometimes not adequately coordinated and integrated, as construction companies are not involved in the design phase[487], and this leads to inefficiencies, delays, and potential errors. This hinders the integration of construction knowledge among stakeholders and professionals, diminishing the opportunity for them to influence design decisions and engage with other professionals involved on the methods, tools and technologies to be used[488]. Failure by professionals involved across all the construction phases to consider how the other team members will carry out the project can result in scheduling problems, delays and disputes during the construction process[489].

483 Information retrieved from interviews.
484 Levelset, Why does it take so long to get paid in construction? And what can I do about it? https://www.levelset.com/blog/why-does-it-take-so-long-to-get-paid-in-construction-and-what-can-i-do-about-it/
485 ECSO (2019). BIM in the European construction sector. https://ec.europa.eu/docsroom/documents/34518/attachments/1/translations/en/renditions/native
486 Nawi, M.N.; Baluch, N.; Bahauddin, A.Y. Impact of Fragmentation Issue in Construction Industry: An Overview.
487 ECSO (2019). BIM in the European construction sector.
488 Nawi, M.N.M., Baluch, N., Bahauddin, A.Y., Impact of Fragmentation Issue in Construction Industry: An Overview.
489 Nawi, M.N.; Baluch, N.; Bahauddin, A.Y. Impact of Fragmentation Issue in Construction Industry: An Overview.

4.2.2 Competition from tech companies

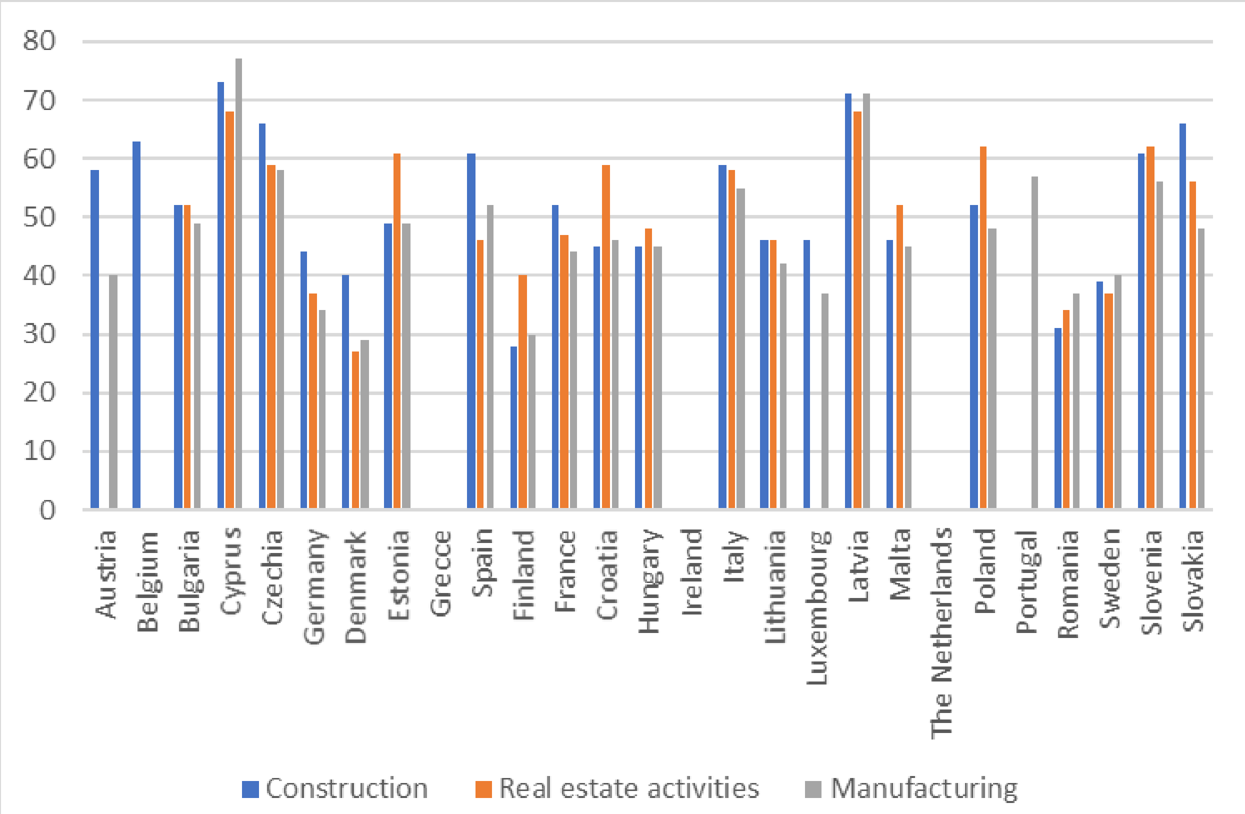
The progressive and growing digitalisation of the construction sector comes with a growing range of actors involved in the process. Indeed, IT companies are more and more engaged in the sector[490], as they have recognised the untapped potential of digital technologies in construction. As a result, the growing demand for digital services is being partially met not by construction companies, but by IT companies, who provide open and interoperable systems and solutions to construction companies, so that they can access critical data, throughout the construction process[491]. In this context, however, concerns arise on the ability of multi-services innovative companies and more traditional construction companies to work together. It has been recently argued that, this situation has "*created a dependency on the software being used in construction works, but also opportunities for the software provider to exploit this dependency*"[492]. This relationship can be assessed by looking at Figure 71, where it can be seen the level of reliance construction, real estate, and manufacturing companies (i.e. the wider construction sector) have on external ICT service providers.

This could lead to a growing gap between IT companies and non-digitalised construction companies, where the latter would rely on the provision of services from IT companies, without having the possibility to upgrade their digital capacities. According to several stakeholders interviewed for this report, this could also impact their market opportunities, which would tend to be circumscribed to construction and maintenance work, where profits margins are relatively low. This would further enhance the digital gap, as lower returns mean less resources to invest in digital technologies and training.

Therefore, the digitalisation of the construction sector offers important market opportunities. IT companies, based on their core business, competencies and human and financial resources have succeeded in seizing part of these business opportunities[493]. In doing so, they support the digitalisation of the construction sector (by e.g.) offering software, but they also limit the potential opportunities of construction firms to lead development in this field.

490 EC, JRC Policy for Science Report.
491 FIEC, FIEC position paper on the relationship between users and software companies/editors/service providers.
492 Ibidem
493 FIEC, FIEC position paper on the relationship between users and software companies/editors/service providers.

Figure 71: Percentage of enterprises (10 persons or more) where ICT functions are only performed by external suppliers (2019 data)



Source: Adapted from Eurostat data

4.2.3 Digital skills

The digital innovation in the construction sector can fully deliver its benefits only if enterprises have access to qualified workforce. This can happen only if construction companies are able to attract, develop and retain skilled and qualified talents. More specifically, tomorrow's construction workforce should be trained in the fields of ICT safety, digital communication, data process, and digital content creation, and should able to communicate and work in digital environments and with digital data, understand the concept of data protection and the precautions to take for safely managing sensitive data[494].

As discussed previously, companies in the construction sector, and in particular micro and small enterprises, often suffer from a lack of a digitally skilled workforce. Overall, digital skills are growingly requested in job advertisements[495], but responses from the ECSO survey confirmed this, putting "lack of skilled human resources" as the one of the main challenge for construction companies, with up to 66% and 60% of respondents saying it is a limit for the specific adoption of Artificial Intelligence and Virtual and Augmented reality, respectively, in the construction value chain. Even for the technologies for which "lack of skilled human resources" scored the lowest, i.e. sensors and Digital Twins, almost a third of respondents selected it as a relevant barrier (see Figure 67). Indeed, while the job vacancies in the sector have grown steeply over the recent years[496], tertiary education and vocational education training (VET) have not grown in line with the existing demand. This trend can be seen in the Figures below, which show the percentage of

494 CECE (2019), Digitalising the Construction Sector. Unlocking the potential of data with a value chain approach.

495 CEDEFOP (2021). Digital skills: Challenges and opportunities. https://skillspanorama.cedefop.europa.eu/en/analytical_highlights/digital-skills-challenges-and-opportunities#

496 ECSO (2020). Human Capital in the Construction Sector.

construction companies struggling to fill ICT vacancies and providing digital training to their employees, in 2015 and 2019. As noticeable, in most countries there has been a significant increase of unfilled ICT vacancies in the construction sector, in front of an only modest general increase in provision of training. This gap is expected to grow, with the European Centre for the Development of Vocational Training estimating that about one million new and replacement workers will be needed by 2025, with an increasing demand for digital and green qualifications[497]. It is therefore not surprising to see that skill mismatch is the most important concern for 79% of construction companies, who wish to invest and build their capacities[498].

While there is no report quantifying the digital skill gap in the European construction sector, there are few indicators showing the depth of this issue. 8% of the construction companies employs ICT specialists, against 19% of other European companies[499]. In addition, construction companies tend to invest less than companies in other sectors in ICT trainings for their employees (14% of construction companies has provided training to develop/upgrade ICT skills of their personnel, against an EU average of 23%)[500]. Going from the EU to the national level, anecdotal evidence show that the digital skill gap is significant. According to Eurostat data, more than 80% of companies in Romania and Sweden have difficulties in finding ICT-skilled workers. This issue is very relevant also for other EU MS, as noticeable from Figure 64 below. For instance, in 2016, it was estimated that France will need to train around 80,000 BIM-qualified workers by 2020[501]. Nonetheless, this barrier is not shared by all MS, as Spain, Portugal, and Slovakia reported low numbers of companies struggling with this.

497 CEDEFOP, Skills forecast 2016.
498 European Investment Bank (2020). EIBIS 2019 - EU overview. https://www.eib.org/en/publications/econ-eibis-2019-eu
499 Eurostat, Enterprises that employ ICT specialists. The numbers refer to companies with 10 or more employees and exclude the financial sector.
500 Eurostat, Enterprises that provided training to develop/upgrade ICT skills of their personnel. The numbers refer to companies with 10 or more employees and exclude the financial sector.
501 Batiactu, Il faudra former 80.000 salariés au BIM d'ici à 2020, selon Syntec-Ingénierie. https://www.batiactu.com/edito/il-faudra-former-80000-salaries-au-bim-ici-a-2020-selon-46393.php

Figure 72: Percentage of enterprises (10 persons or more) in the narrow construction sector (NACE-F) which had hard-to-fill vacancies for jobs requiring ICT specialist skills (2015 and 2019 data)

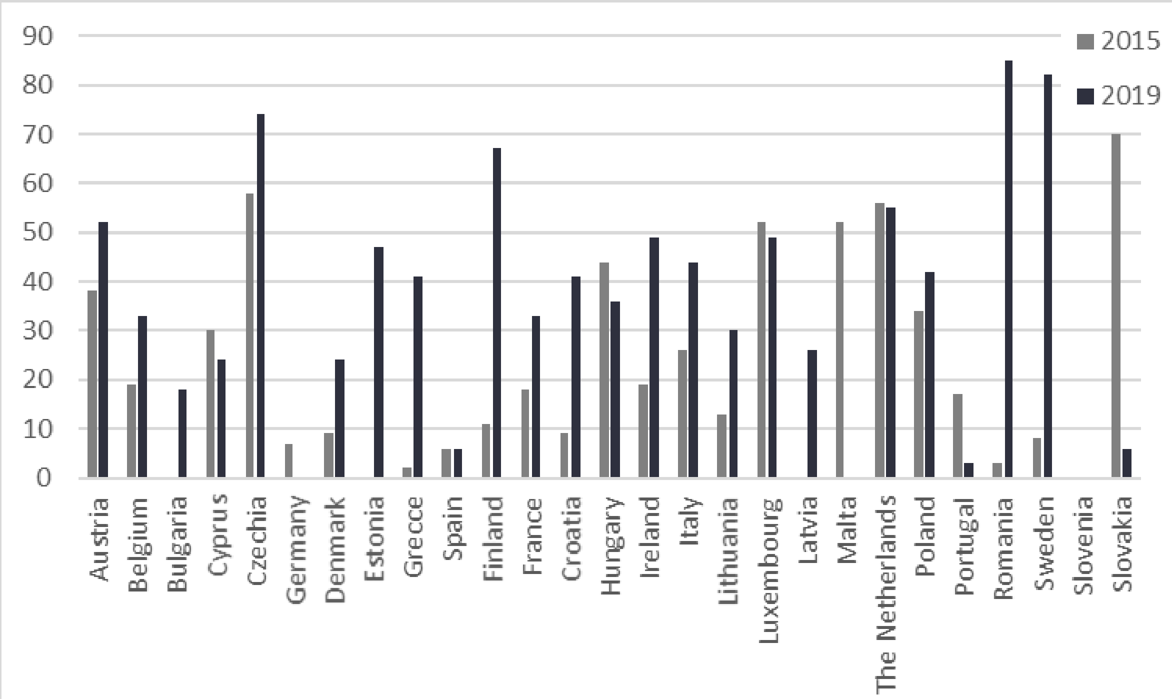
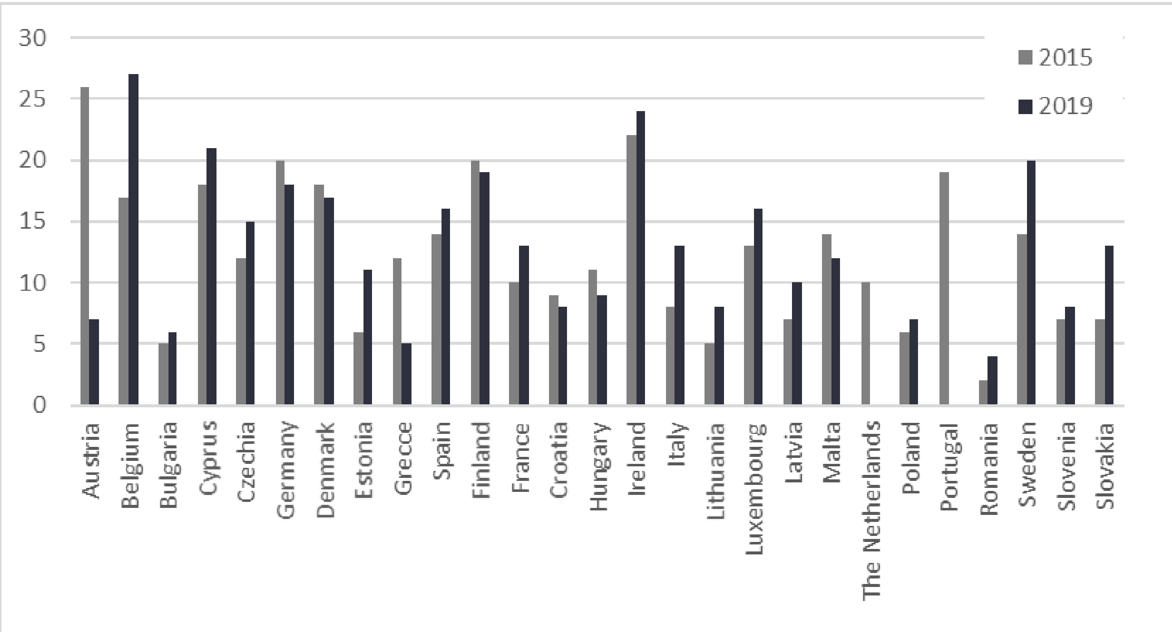


Figure 73: Percentage of enterprises (10 persons or more) in the construction sector (NACE-F) which provided training to their personnel to develop their ICT skills (2015 and 2019 data)



Source: Adapted from Eurostat data

One of the reasons behind the shortage of qualified workforce is the traditional image of the construction sector. Compared to many other industries, the construction sector has traditionally been slow at technological development and has undergone no major disruptive changes in the last decades[502]. The image

[502] World Economic Forum, Shaping the Future of Construction. A Breakthrough in Mindset and Technology.

that people have of the construction sector as an employer is not necessarily innovative and hence not related directly to digital skills[503]. Furthermore, the sector is often associated with long hours, harsh working conditions and low salaries[504]. Hence, young graduates studying ICT may not be aware or interested in a career in the construction sector. As a result, companies struggle to recruit skilled workforce, as the sector is often not seen as a potential destination for (young) qualified individuals, who then tend to prefer other sectors with a more innovative and dynamic image[505].

SMEs struggle to attract the limited skilled workforce, as reflected in the low investment in developing/upgrading ICT skills. This is linked to two issues: i) training and upskilling employees demand financial resources, which SMEs do not necessarily have; and b) once trained, those same employees profile will be of great interest for larger companies (which can offer better wages than SMEs)[506]. Hence, SMEs are reluctant to invest in developing digital skills, by the fear that such investment will not be profitable on the short to mid-term. This in turn contributes to increasing the gap between SMEs and large companies in terms of adoption of digital technologies.

Finally, participation in VET programmes in the construction sector is lower than in other sectors[507]. This is particularly relevant when considering that low-skilled workers are at the highest risk of losing their jobs and, at the same time, they are three times less likely to take part to training programmes[508]. The main reasons behind this underperformance are the high costs of trainings for individual workers, who may not be able to afford such an investments, poor coordination between VET institutions and construction enterprises, and the issue for smaller companies to invest in trainings for their employees, as the benefits of the training (e.g. more efficient and productive workforce) come only after the required upfront investment[509]. Lastly, and in connection to what stated above, the sector has failed to build an image of innovation, hence often not being considered as a sector where upskilling and training are needed.

4.2.4 Cybersecurity

As the construction sector becomes more and more digitalised, the topic of cyber security becomes more and more important[510]. When using digital tools across the different phases of the digital construction process, numerous and different actors collaborate in a digital environment. Many project stakeholders, from contractors and sub-contractors to architects, engineers and managers have access to shared IT platforms where design, construction and maintenance data is stored and used. The sheer volume of digital confidential data (e.g. budgets, bid information, technical drawings and product design, trade secrets, employees' data) will inevitably increase, with added security risks[511].

The increased usage of tablets, smart phones and laptops represents an increase in potential system vulnerability entry points[512], as cyber-attacks through, for example, USB keys containing malwares or public Wi-Fi networks will likely become more common. This is further aggravated by the heavy reliance on sub-contractors, which multiply the number of potential cyber security issues[513], as the number of

503 The image of the construction industry and its employment, attractiveness. https://www.ajol.info/index.php/actas/article/viewFile/151802/141414
504 ECSO, Analytical Report. Human Capital in the Construction Sector.
505 WEF, Shaping the Future.
506 Information retrieved from interviews.
507 ECSO, Analytical Report. Human Capital in the Construction Sector.
508 PwC, The Lost Workforce: Upskilling for the Future. https://www.pwc.lu/en/upskilling/docs/pwc-wgs-report-the-lost-workforce.pdf
509 ECSO, Analytical Report. Human Capital in the Construction Sector,
510 EC, Supporting the Digitalisation of the Construction Sector and SMEs.
511 Constructible, the importance of cybersecurity in Construction. https://constructible.trimble.com/construction-industry/the-importance-of-cybersecurity-in-construction
512 EC, JRC Policy for Science Report.
513 Locktown International, Cyber Attacks in the construction industry. https://www.locktoninternational.com/gb/index.php/articles/cyber-attacks-construction-industry

professionals and devices that have access to the digital data and that would need to uphold high cybersecurity standards is higher[514]. For example, BIM is a model that allows input from various parties, either working independently or working on the same integrated model at the same time. Due to the shared nature of BIM and the numerous connected parties, the risks of a data security breach are much greater[515].

In addition, the importance of data privacy and confidentiality in the construction sector will grow exponentially. At the European level, the GDPR was approved in 2016 and entered into force in 2018. It provides a thorough regulatory framework when it comes to data protection and privacy. As contractual relations between service providers and clients include the gathering and use of increasingly large quantities of data coming from sensors, digital models, connected devices, etc., ensuring the transparent treatment and protection of such data not only from security breaches, but also from unlawful commercial uses will be required[516].

Concerns about cybersecurity come also from the software used. Indeed, European construction companies heavily rely on software being developed by non-EU companies. This poses challenges not only in terms of European digital autonomy, but also in terms of data ownership, as once European data are stored in foreign databases, companies have little guarantees that European standards are respected[517].

This requires companies to step-up their digital security systems and controls, both internal and external, as well as provide appropriate training to their employees so that they are able to safety utilise digital tools, comply with the legislation, and recognise potential security threats[518,519]. Companies need to review their practices and policies to ensure optimal compliance with the GDPR and other legal requirements as their business rapidly shifts towards the use digital data.

4.2.5 Standardisation of data formats and interoperability

Given the recent and rapid emergence of digital technologies in the construction sector, the issue of standardisation has been gaining importance, as it is pivotal for the interoperability of different digital tools. The construction sector, like many other industries, is governed by numerous standards, regulations, guidelines, and requirements. These are meant to make construction projects safer and more efficient; however, they also represent an important challenge when it comes to cooperation and **interoperability of new technologies in this sector**[520]. Industry standards are critical to ensuring safety and quality, efficiencies across processes, and data capture[521]. Given the heterogeneity of the actors involved in the construction value chain, the standardisation and, therefore, interoperability of the data they provide and use, is pivotal for the effective and successful deployment of digital technologies across the entire value chain.

A key challenge faced by companies in the construction sector is the current lack of a common standards when sharing information (i.e. data) and the absence of an agreed understanding of the information required at the various phases of the construction value chain. In fact, there is a gap for developing data standards for the wider construction sector that are accessible and applicable by all actors across the value

514 RICS Trend Paper (2019). The use and value of commercial property data.
515 Locktown International, Cyber Attacks in the construction industry
516 Eversheds Sutherland, GDPR – is it relevant to the construction industry? https://www.eversheds-sutherland.com/global/en/what/articles/index.page?ArticleID=en/Construction_And_Engineering/Foundations-uk-article-gdpr-april-2018
517 FIEC, FIEC position paper on the relationship between users and software companies/editors/service providers.
518 Construction dive, Cybersecurity expert: All construction data 'is an asset and should be protected'. https://www.constructiondive.com/news/cybersecurity-expert-all-construction-data-is-an-asset-and-should-be-prot/573037/
519 EESC, Opinion, Trust, privacy and security for consumers and businesses in the Internet of Things (IoT).
520 EC, JRC Technical Reports. Building Information Modelling (BIM) standardization.
521 Oracle, The pathway to success: Standardization in the E&C industry. https://blogs.oracle.com/construction-engineering/success-standardization-ec-industry

chain[522]. This is further complicated by the different software, data formats and terminologies used across the industry and the range of information requested from multiple construction disciplines[523]. In the construction sector, tendencies to optimise at individual or organisation level only can be observed, as the sector is highly fragmented, and nobody owns in the whole process in construction[524], thus reducing the incentives to develop common standards outside the individual company of phase.

Standardised data templates and formats would provide a consistent approach for product manufacturers by providing a specific format for a precise data type that can be understood and used by all actors in the value chains. These data templates would then allow digital construction data processes, for example from BIM, to be automated and to have a higher degree of reliability, thus favouring a more widely use of digital tools. Data standardisation will also support the delivery of sustainable construction projects by providing information in a homogeneous way[525], thus allowing both project promoters and customers to more easily compare sustainability data (e.g. energy efficiency and waste produced) from different buildings.

Respondents to the survey carried out for this report indicated that "lack of standards" as one of the main challenges, particularly relevant for digital innovations such as BIM, sensors and Digital Twins. These results are in line with those from another survey, in which 83% of respondents stated that EU BIM standardisation would foster homogeneous BIM adoption across the EU[526]. In this context, some progresses have been made, as highlighted in the previous sections. **The European Committee for Standardisation has officially adopted BIM standards** (CEN/TC 442: IFD (ISO 12006-3:2007), IFC (ISO 16739:2013) and IDM (ISO 29481-2:2012), to create a common language when sharing information and an agreed understanding of the information required at the various stages of a project[527]. However, there is still a margin of improvement when it comes to standardisation of the different digital technologies, as shown in the survey results presented in 5.3 Lessons learnt .

522 RICS Trend Paper (2019). The use and value of commercial property data.
523 BIMPlus, Comment: Martyn Kenny - In BIM world, we need standardisation. https://www.bimplus.co.uk/people/lafarge-tarmac-seeks-common-language/
524 EC, JRC Technical Reports. BIM standardization.
525 Ibidem.
526 Charef, R.; Emmitt, S.; Alaka, H.; Fouchal, F. (2019). Building Information Modelling adoption in the European Union: An overview. Journal of Building Engineering 25 100777
527 EC, ECSO, Building Information Modelling in the EU construction sector.

5. Conclusions and lessons learnt

There is general consensus that the digitalisation of the European construction sector is both inevitable and pivotal for the competitiveness and sustainability of the sector. Digital transformation brings numerous opportunities for European companies, but also important challenges. This Analytical Report provided an overview of the state of play in the uptake of digital technologies in the EU construction sector, and some of the public policies and instruments put in place to support and foster their adoption.

The findings of this report show that the idea that the construction sector is not able and/or interested in digital transformation does not correspond to the reality. In fact, a number of technologies are at a mature stage of development and are now increasingly being adopted and mainstreamed by companies in the sector. While there is still room for improvement, technologies such as BIM or sensors have proven to be market-ready and are regularly being used in bigger construction projects. However, there are also significant challenges which prevent the sector from reaching a stage of homogeneous and widespread implementation of the digital technologies across the construction value chain, in particular when it comes to micro and small enterprises and smaller projects.

Based on the analysis conducted in the previous chapters of this report, Chapter 5 provides a set of conclusions and policy recommendations on the issue of digitalisation in the construction sector. It first starts with the main insights of the report and general observations, before delving into the lessons learnt.

5.1 Main findings

This report, in providing the state of play of the key digital technologies adoption in the EU Member States, shows that the EU construction sector is progressing regarding its uptake of digital technologies. Whether they relate to data acquisition, automating processes or digital information and analysis, digital technologies are deeply interconnected increasingly present in the construction sector, being applied in all its value chain phases, from the design and construction phases, to operation and maintenance. However, their level of adoption also differs, following i) their size and ability to invest; ii) their market maturity and technological readiness; iii) the perceived benefits (and for which actor); and iv) the market and policy/regulation constraints and opportunities.

Among the most adopted digital technologies figure sensors, drones and BIM. That said, the report also highlights the potential of forward looking digital technologies such as AI and Digital Twins (for buildings and cities), which seem to generate significant traction and interest from both policy-makers (see e.g. the EU strategy and investment in AI) and industrial stakeholders. It is important to underline that, while the report analysed the digital technologies individually, their combination is common practice and allows to maximise the benefits relating to digital transformation. To give an example, 3D scanning, BIM, Augmented reality and Digital Twins are deeply interconnected, as they refer to technologies leveraging on each other and can be seen as different stages or elements of the same digital transformation (e.g. augmented reality in the construction sector can be seen as the combination of BIM models with visual sensors; a Digital Twin is a BIM model regularly updated by using data from several sensors, scanners, etc.). For this reason, the maturity and adoption of an individual digital technology are intrinsically linked to the development of other technologies and should not be seen as a stand-alone process.

By analysing policies, this report shows that the public sector plays a key role in supporting, incentivising, pushing for the uptake of digital technologies in the construction sector. It does so through mainly three types of interventions: i) as policy-makers, being able to set the rules of the game and lead the digitalisation process; ii) as buyers and administrators of buildings and infrastructures, being able to influence the market, by providing business opportunities; and iii) as building-related public services administrators, hence having the possibility to digitalise their own processes first – so as to facilitate the digitalisation uptake down the value chains. The report notably demonstrated the interest of policymakers in supporting the digitalisation of the construction sector with 60% of the strategies analysed touching upon this issue. These strategies often come accompanied by additional tools such as financial but also technical assistance type of support such as for digitalisation construction platforms. The latter are in fact particularly useful in enabling collaborations, synergies and knowledge sharing within the construction sector (which is an important aspect given its fragmentation).

In addition, several national governments chose to foster the adoption of digital technologies in construction projects by requiring their use in public procurement tenders. The feedback collected from both the industry and the public sectors indicate that this is an area that can be particularly beneficial to foster the digitalisation of the construction sector. However, in developing such requirements, public sector actors may also need to i) build their BIM related capacities; ii) balance their focus between low price and high quality; iii) and make sure that all types of companies (small and large) can leverage on these opportunities to digitalise. Last, governments also facilitate the uptake of digital technologies in the construction sector by providing e-services. When it comes to construction, national and local governments have a direct impact on public services related to the built environment[528], by e.g. issuing building permits and keeping the repository of building data and geospatial information (cadastre). These could facilitate the uptake of digital technologies. In this regard, an increasing number of EU Member States have adopted digital building permits systems and registries of properties. More than their growing spread, their level of sophistication is evolving as well, with the inclusion of Geographic Information System (GIS) and 3D models for digital registry of properties for instance.

Overall, with the recent development at the EU level – in terms of policies (such as the Renovation Wave strategy), support measures (e.g. development of a methodology to assess BIM benefits), funding streams (Recovery and Resilience Facility, new MFF, etc.), it can be expected that national governments will be incentivised to do more to support the digitalisation of their construction sector. This will be crucial to support the transformation of the sector and its growth, but also to reach climate and sustainability related objectives. However, to be effective, any policy intervention should be evidence-based and carefully monitored throughout its implementation in order to adjust to possible changes and reflect the interests and constraints of construction actors and other public and private stakeholders.

Policies and regulations are hence considered as one of the key drivers for the digitalisation of the construction sector. More specifically, EU and national government policy and regulation are the only driver deemed by over 60% of respondents as important to a high or very large extent according to the survey results. This is followed by government and business needs for a better access to information and better decision making. Market drivers are also important - such as companies needs to improve productivity, cut costs or even the importance of the market demand in the uptake of digital technologies in the construction sector. Between 50% to 57% of stakeholders consider these drivers as important to a high or very large extent. In this context, it is important to highlight the role of both large companies and start-up/SMEs, which play a different and complementary role in supporting the adoption of digital technologies in the sector.

[528] Built Environment is defined as the product of construction. It is the human-made space in which people live, work, and recreate on a day-to-day basis including buildings, parks, public spaces and infrastructure for utilities, mobility and leisure.

Importantly, though the COVID-19 outbreak affected the activities of construction companies, it pushed both the private and public sector to adapt their services and delivery mode in order to cope with restrictions. In that sense, COVID-19 may push the construction sector towards a new normal, where digital technologies play a more important role, spreading at the different stages of the value chain.

This report also underlines some of the key challenges that undermined and still undermine the digital transformation of the construction sector. According to the survey results, cost of equipment and software, lack of skilled workforce, and lack of awareness and understanding are the three main factors hindering a faster and broader digitalisation of the European construction sector. It is important to put this finding in perspective by highlighting the fact that the importance of these challenges also vary according to the technology: the cost of equipment is an important limiting factor for 3D printing and robotics, but it is a secondary issue for the adoption of sensors. In addition to the aforementioned challenges, the report also looks at the issues relating to the inherent fragmentation of the construction sector, cybersecurity and standardisation. However, the introduction of policies and instruments at the EU and national level should allow alleviating the weight of these challenges on the digital transformation of the construction sector.

Before delving into the lessons learnt and the ways forward, the report will present in the section below a set of general observations. These were identified throughout the development of the report, and show the complexity of addressing the issue of the digitalisation of the construction sector from a policy perspective.

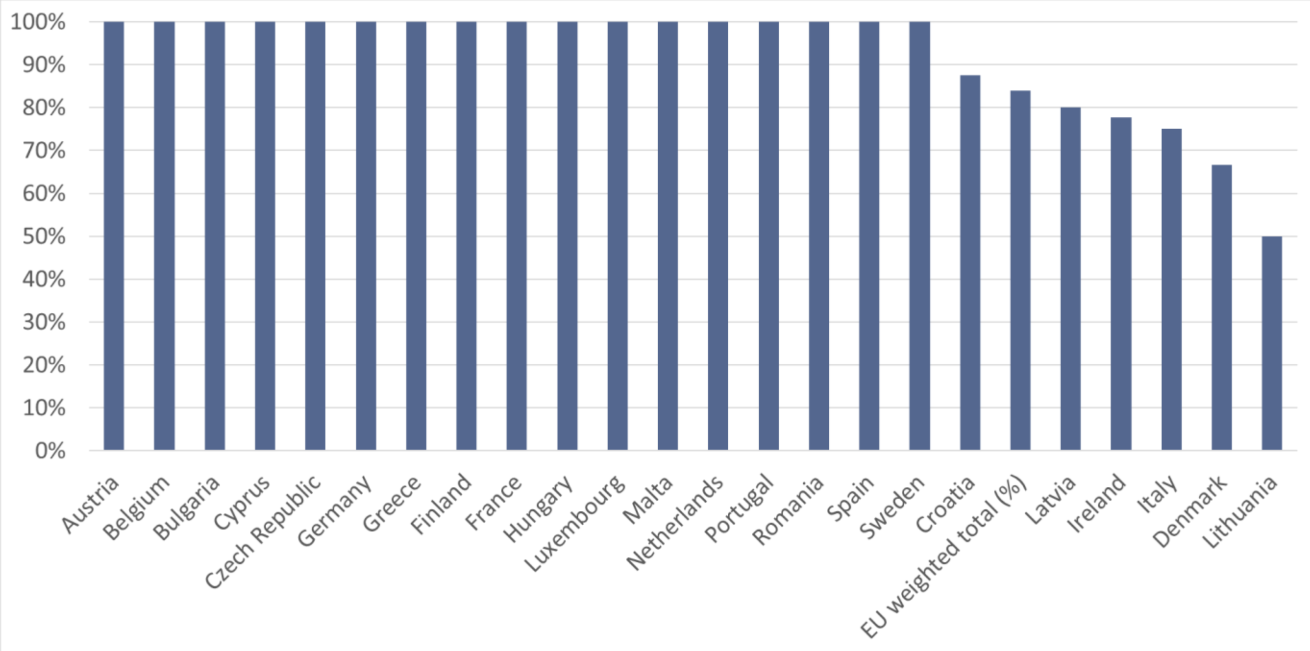
5.2 Observations

First, it is important to highlight that EU data on the digitalisation of the construction sector is limited, which impedes the development of evidence-based policy making. The available data on digitalisation rarely refers to the construction sector, and when it does, it rarely covers all EU-27 Member States in a robust and comparable way. Instead, reports available in the public domain indicate rather anecdotal evidence, based on ad-hoc surveys and interviews (the results of which are not always accessible – thus limiting their use). The main (if not only) exception is the EIB Investment Survey and the EIB digitalisation index, which provides data on investments and digital technologies in the construction sector. Moving forward, it will be crucial for the EU and its Member States to collect and analyse data on the digitalisation of the construction sector that can better inform policy developments and reviews. To do so, public institutions will need to work hand in hand with EU and national construction associations – which have already been collecting data on this issue.

Second, while this report focuses on a limited number of policy initiatives, such a selection already indicates that there is no "one-way" model of supporting digitalisation in the construction sector. Depending on the national context including the market structure and development of the construction sector, and policy objectives, policymakers have opted for more than one type of support – whether in the form of financial instruments, policies or regulations. This shows that the digitalisation of the construction sector requires a holistic understanding of the sector and approach, balancing between incentives and requirements; between developing construction specific/tailored instruments and generic initiatives; and between regulating to protect citizens' rights and helping create market opportunities for digital technologies and ensuring the competitiveness of the sector. In other words, and also linked to the interconnection among technologies mentioned above, policymakers need to embrace this complexity to put forward holistic policies and initiatives that can best support the digitalisation of the sector. The deployment of forms of public support to specific digital technologies, e.g. BIM, sensors, and 3D scanners, will also tow the development of other technologies, such as Digital Twins, Augmented Reality and Artificial Intelligence. This factor should be taken into consideration when developing policy initiatives.

Third, as seen in this report and as acknowledged by most stakeholders interviewed, the EU should play a role in supporting the digitalisation of the construction sector (and in fact already is doing so). The EU has demonstrated in previous years that it could lead the way when it comes to fostering the adoption of digital technologies in Member States – through its direct or indirect policies and regulatory acts (e.g. via the EU Directives on Public Procurement). However, as the state of play of digitalisation differs from one country to another, such support – to be effective, should either be tailored to EU Member States, or allow for Member States to tailor it to their national context.

Figure 74: Share of stakeholders seeing a need for an EU policy intervention to support the digitalisation of the construction sector per country.



Source: ECSO survey, 2020

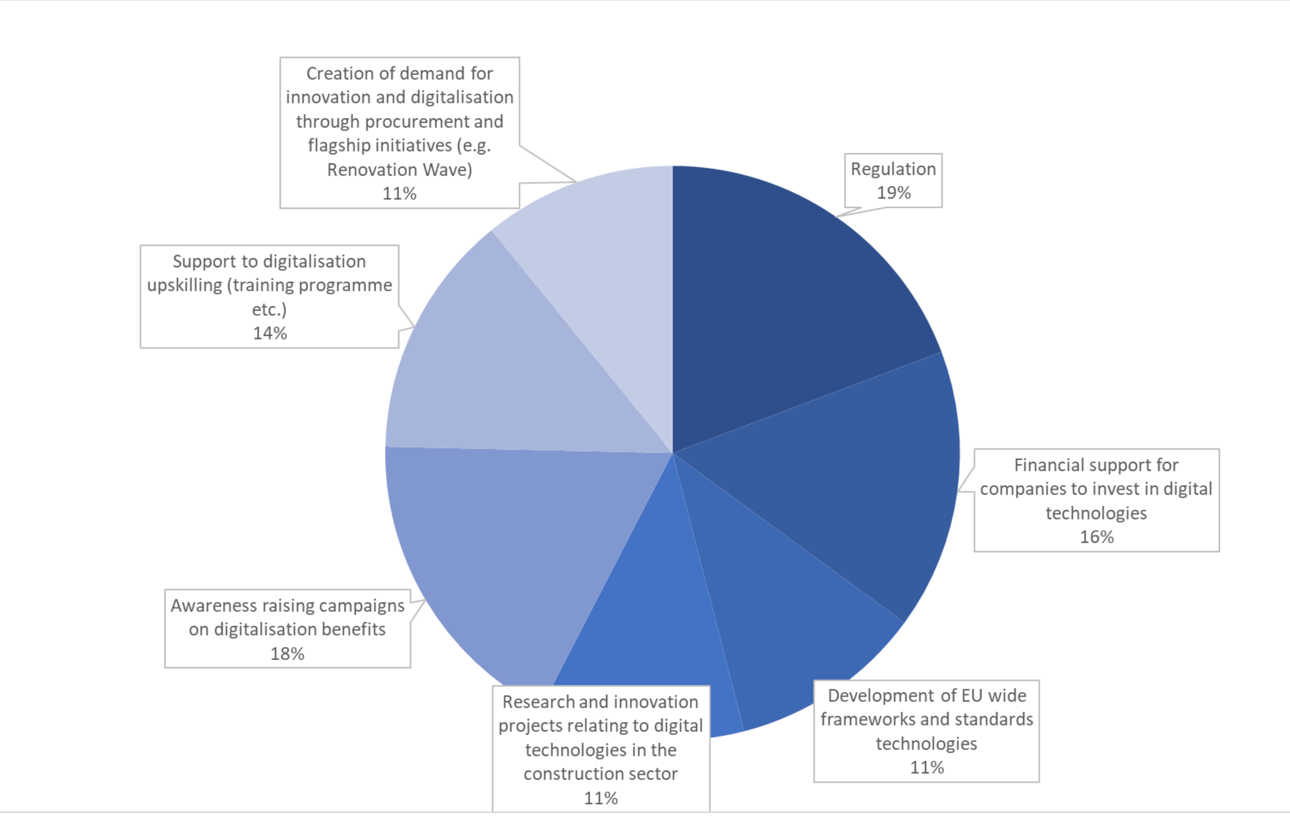
The figure above shows that 100% of construction stakeholders in 17 countries (out of the 23 where answers were provided) all agree on the need for an EU policy intervention. This rate is lower in Croatia, Latvia, Ireland, Italy, Denmark and Lithuania where it goes down to 50%. However, this also means that in **all EU countries surveyed, the majority of stakeholders would like to see the EC supporting the digitalisation of the construction sector**. Such an EU policy intervention should be complementary and/or additional to national policies and programmes.

5.3 Lessons learnt

As highlighted in the previous sections of this report, the EU can leverage on a wide range of (direct or indirect) policies and instruments to accompany and boost the digital transformation of the construction sector. This section highlights some of the recommendations survey respondents formulated in terms of what type of interventions the EU should develop to help transform the construction sector and support its companies (from micro, to SMEs and large companies) to digitalise, as illustrated in the graph below.

The results of the survey indicate that regulations, awareness raising campaigns on digitalisation benefits and financial support to construction companies are the top three areas the EU should focus on to make a difference. Together, these account for over half of the total number of responses. This is followed by policy intervention focusing on developing digital skills; supporting research and innovation projects; incentivising digital technologies through public procurement; and finally establishing EU-wide framework and standards. These results are reflected in the responses received from stakeholders in most EU Member States - the top three EU policy interventions deemed relevant account for more than 50% of responses.

Figure 75: Most relevant EU policy intervention to foster the digitalisation of the construction sector



Source: ECSO survey, 2020

Figure 76: Most relevant EU policy interventions to foster the digitalisation of the construction sector, per country

Source: ECSO survey, 2020

These results echo some of the drivers and barriers observed in this report. First, digitalisation comes with numerous challenges in the field of data collection, exploitation, analysis and sharing, which are further amplified by the fragmentation of the construction sector (see section 4.2.1 Fragmentation of the construction sector and section 4.2.5 Standardisation of data formats and interoperability). A standardising regulatory framework such as the one envisaged for the creation of the Single Market for Data under the European Data Strategy will be of prime importance to ensure better data quality and data management, address challenges around intellectual property rights, cybersecurity, and data ownership (see section on Regulation). Such a framework should protect data privacy and foster interoperability, while also enabling the private sector to seize further market opportunities and remain competitive. What is important here is the fact that such framework, in order to be as effective as possible, should be set up at the EU level so as to support businesses collaboration and involvement in the entire EU Single Market. According to stakeholders interviewed, one additional area where regulations can also play a role is in terms of ensuring competition when it comes to the provision of IT solutions and software, where construction firms are increasingly dependent on technology companies. The latter leverage their relationships with construction firms to offer services based on a pricing and business model (e.g. subscription) that can undermine the broader uptake of digital technologies by construction firms (see 4.2.2 Competition from tech companies).

Second, the EU can play a key role in raising awareness of digital technologies – especially among SMEs, which are often unaware and/or not convinced of the benefits of digitalisation. This can be illustrated by the recent tender published by the EC, on "supporting actions for the digitalisation of construction SMEs"[529]. This upcoming project provides for the training aiming to improve the digital maturity of EU construction SMEs and tools to help SMEs assess their own digital maturity level. To raise awareness of digital technologies, the EU can rely on EU and national construction associations which can leverage on their network to raise awareness. Such awareness raising campaigns can take the shape of (but should not be restricted to) events, workshops, best practice type of publications, or competition for a prize. For instance, the EC commissioned a study[530] for the development of a cost benefit analysis and tool around the adoption of BIM. With this approach, public sector institutions can go beyond activities limited to listing the benefits of BIM, by showing the concrete business case behind the implementation of digital technologies. In addition, as we saw in this report, the EU can play a key role in raising awareness not only among companies adopting digital technologies, but also among consumers (whether households, public and private sector entities), thus contributing to support the demand for digital technologies. This is perhaps one of the most crucial points, as several interviewees recognised that "construction firms will do anything their clients ask for". Finally, awareness raising activities should not be limited to demonstrating the benefits of digital technologies, but also some of the main tools, software, approaches and processes relating to their adoption, which would help guide SMEs on their digital transformation journey.

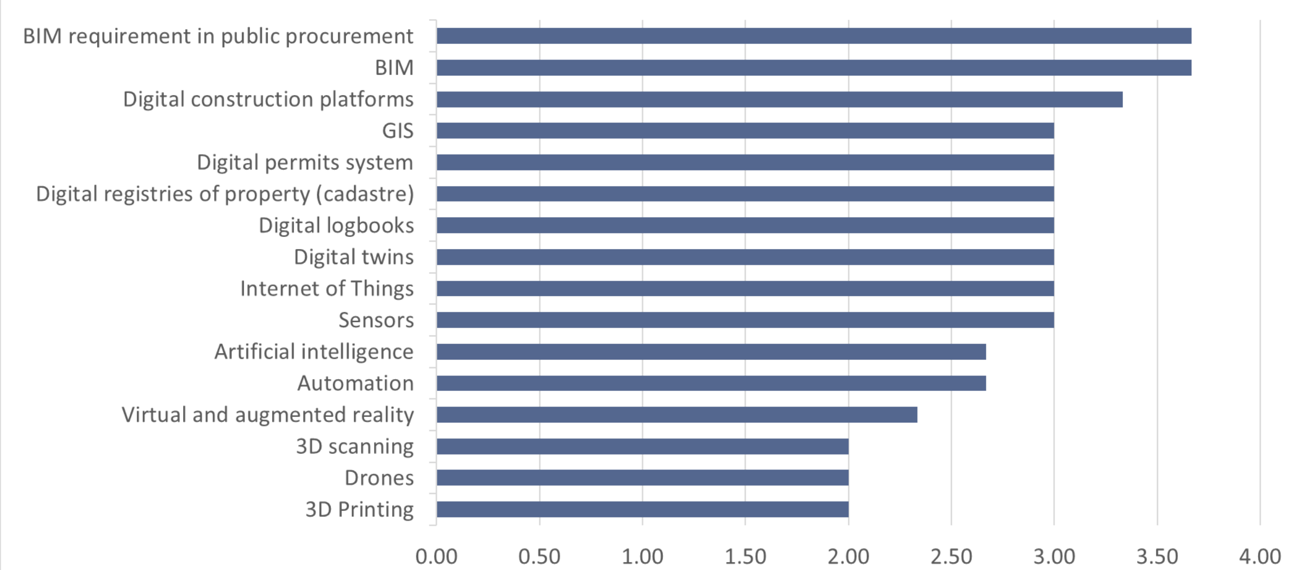
Third, the EU should continue providing financial support to companies, and especially SMEs, to invest in digital technologies. As mentioned in this report (see 3.1.2 Funding), several policies and instruments will be put in place to support investments throughout e.g. research and development activities covering the full (digital) innovation process – covering the ideation, proof of concepts, prototype, market validation and product market fit stages. In addition, the uptake of digital technologies will be supported by investment programmes such as InvestEU and the EU Recovery and Resilience Facility – whether in the form of grants, or financial instruments such as guarantees, loans and equities. Importantly, many EU schemes also accompany their financing component by a technical assistance component. This dimension should not be overlooked as technical assistance can help investments become viable and maximise their impacts. This is particularly relevant in the context of digitalisation, which is a complex process requiring specific knowledge and competencies. Last, several interviewees noted that making financing available is not enough to activate SMEs when it comes to digitalisation. Awareness of financing opportunities among SMEs is key and the application process should also be tailored to their limited capacities and available resources to avoid discouraging them from applying. If not directly mitigated at the EU level, this issue could be tackled by construction associations or national public institutions that could play a facilitation/intermediation role in supporting construction SMEs.

In addition, it is important to note that the stakeholders' interest in an EU support intervention also varies according to the digital technology targeted. In this regard, the figure below indicates that BIM, but also digital permit systems, digital registries, GIS and digital logbooks are among the top five technologies attracting most interest. Interestingly, some of these digital technologies have to do with the construction process (BIM), while others (permit system, registries or logbooks) relate more to the digitalisation of public services related to construction processes involving both private and public stakeholders. This shows that stakeholders are interested in the digitalisation of public services, which can in turn speed things up and facilitate the integration of digital technologies in the construction process. The interest in BIM is explained by three main factors: i) BIM is already included in policy intervention (originally stemming from EU Directive

529 See more information at: https://etendering.ted.europa.eu/cft/cft-questions.html?cftId=7219
530 See more information at: https://ec.europa.eu/easme/en/tenders/methodology-cost-benefit-analysis-use-bim-public-tenders

on Public procurement); ii) BIM is also the most mature digital technology in the construction sector – perhaps indicating less resistance from market actors, and more awareness vis-a-vis the benefits but also the business case around the use of BIM; and ii) for some stakeholders, the spread of BIM will impact the uptake of other digital technologies – generating a snowball effect.

Figure 77: Most relevant digital technologies EU policy intervention should focus on (0 = Not Important; 1 = Slightly Important; 2 = Moderately Important; 3 = Important; 4 = Very Important)

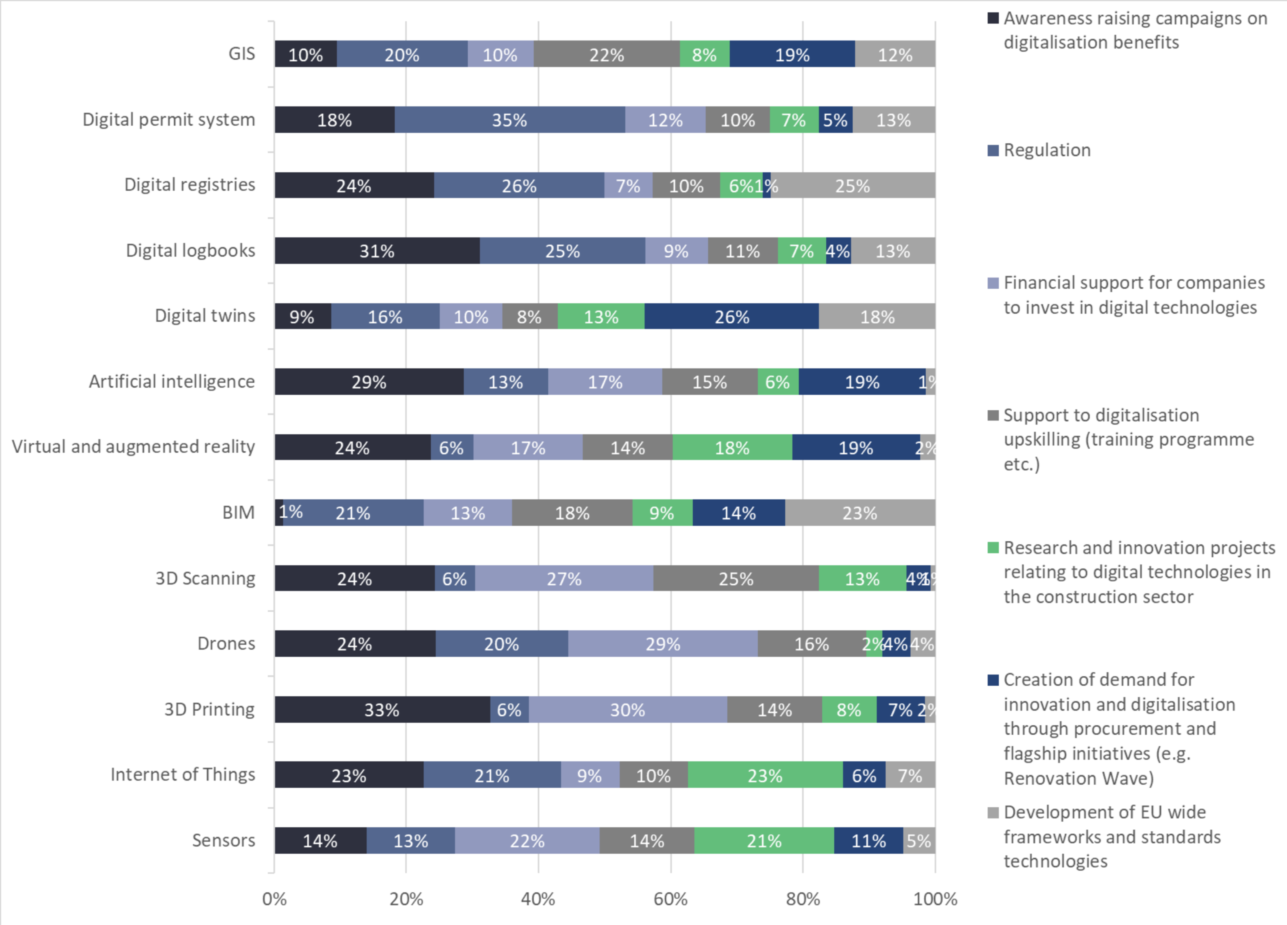


Source: ECSO survey, 2020

The figure below shows a different angle of the analysis, by looking at the most relevant type of EU policy intervention according for each technology. The ranking is consistent with the ones presented above showing again that the top three relevant EU policy interventions have to do with: raising awareness; regulating and providing financial support for the uptake of digital technologies in the construction sector.

When looking further into each technology, some trends can be distinguished. In the case of BIM, integration in public procurement is highlighted by stakeholders as one of the most relevant policy areas where the EU (has done and) can do more in the future. Moving forward, the development of an EU framework and regulations seems to be particularly important for technologies such as digital logbooks and registries and digital permits systems. This may be explained by the fact that these technologies relate more to the digitalisation of public services, and their harmonisation at the EU level would allow EU construction companies to access the EU Single Market more efficiently.

Figure 78: Relevance of type of EU policy intervention per digital technologies (EU weighted average %)

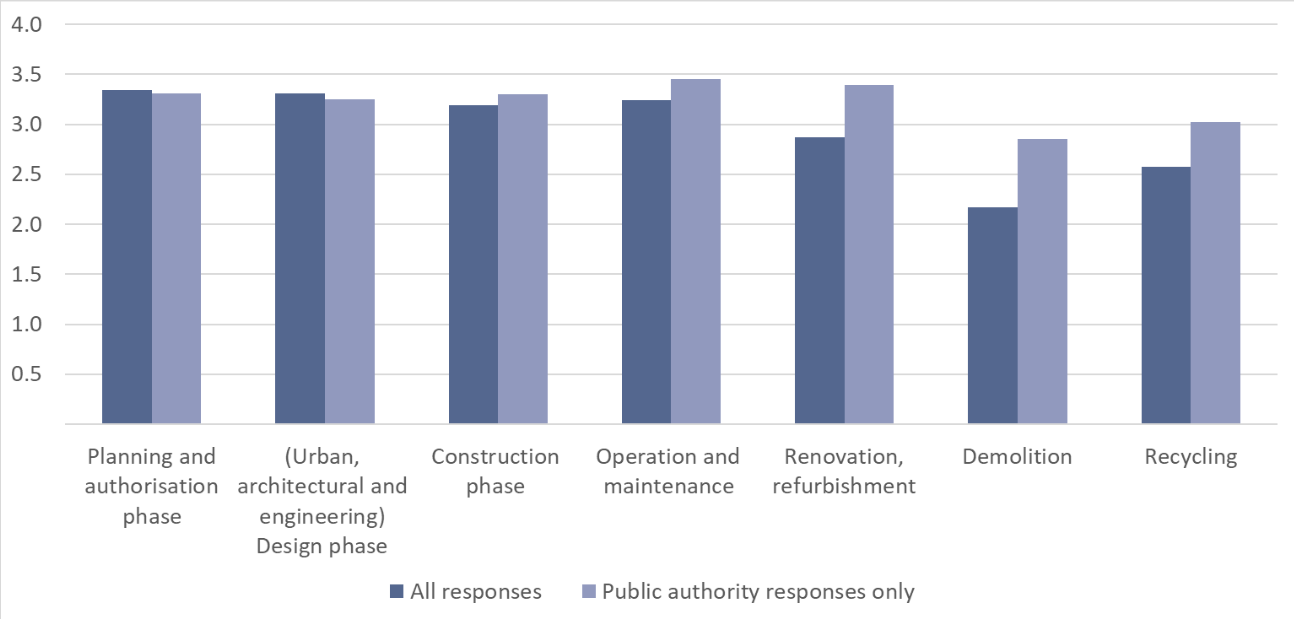


Source: ECSO survey, 2020

As elaborated in this report, the integration of digital technologies is also uneven throughout the construction value chain. This may be due to the inherent characteristics of the digital technologies that are only applicable in specific stages, or because of the lack of interest/appetite of specific actors in the value chain. The figure below provides an overview of the phase of the construction value chain considered most important to achieve digitalisation of the construction ecosystem.

It shows that the planning, design, construction, operation and maintenance phases are very important when it comes to the digitalisation of the sector. In turn, this may indicate where potential EU intervention should focus on. Last, the renovation, demolition and recycling phases were assessed to be of moderate importance. This result does not mean that these phases should be ignored by EU policymakers, but that they are less of a priority as of today. In fact, as explained throughout this report, the uptake of digital technologies in later stages of the construction value chain has influenced their adoption in the earlier stages: if no BIM model was introduced in the planning or design phase of a building, chances to use BIM during the renovation phase are limited. In addition, for businesses to engage in digitalisation, clear benefits and business cases need to be identified beforehand. In this regard, the application of digital technologies in the renovation and recycling phases is not yet widespread and generally less mature than in other parts of the construction value chain.

Figure 79: Importance of phase to achieve digitalisation of the construction ecosystem across the EU (0 = Not Important; 1 = Slightly Important; 2 = Moderately Important; 3 = Important; 4 = Very Important)



Source: ECSO survey, 2020

It is interesting to note that the responses of the stakeholders from the public sector differ from those of private sector. For public authorities, the renovation, demolition and recycling phases are of similar importance to achieve the digitalisation of the construction sector as the four previous phases. This indicates at least two things: i) a shift in approach of policy makers from traditional construction, to circular construction and the importance of thinking in a holistic manner about the sector; and ii) the awareness that renovation of buildings will be a prime policy focus, and that, as part of it, they need to leverage on the opportunities that this will provide to the construction sector, to incentivise companies to integrate digital technologies.

In conclusion, this chapter highlighted that an EU policy intervention to support the digitalisation of the construction sector is desirable, from the perspective of national stakeholders. It identifies i) the type of policy; ii) technologies; and phases in the construction value chains where an EU intervention could complete and support national initiatives. In doing so, it showed that developing and implementing a policy intervention in the construction sector is a highly complex exercise, that needs to be thought in a holistic manner – not only from a sectoral, but rather from a systemic perspective (i.e. including horizontal policies). In addition, such an intervention ultimately aims to have an impact on the sector and its actors, it is key to identify where the interests of the private and public sector best aligned, in terms of e.g. support to specific part of the value chains. An EU policy intervention could thus start by supporting the digitalisation of the actors in the first phases of the construction value chains, where the private sector demonstrated most interest and appetite for digital technologies. Importantly, any policy interventions developed should be flexible to reflect the changes relating to digital transformation and technologies. This is even more important as digital technologies' relevance can shift quickly. Last, it is important to note that any EU policy intervention should be evidence-based, and backed by sufficient data (qualitative and quantitative) on the digitalisation of the construction sector. This report is a first move towards that direction, and where future studies can build on to delve into specific issues and topics.

Bibliography

Belos et al. (2015). Electronic building permission system: The case of Greece.

Buildings Performance Institute Europe (2020). A Review of EU Member States' Long-term Renovation Strategies.

Bulgaria's Ministry of Transport, Information Technology and Communications (2020). Digital Transformation of Bulgaria for the period 2020-2030.

CITA (2017). Global BIM Study.

Committee for European Construction Equipment (2019). Digitalising the Construction Sector. Unlocking the potential of data with a value chain approach.

Croatia's Ministry of Public Administration (2017). E-Croatia 2020 Strategy.

Deloitte (2018). European Construction Monitor 2017–2018: A looming new construction crisis?

Deloitte (2019). Point of View on Digital Construction.

Electrical Engineering and Computer Science (2018). Opinion, Trust, privacy and security for consumers and businesses in the Internet of Things (IoT).

EUBIM (2017). Handbook for the introduction of Building Information Modelling by the European Public Sector.

European Commission (2020). A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives.

European Commission (2020). Accelerating the digital transformation of government.

European Commission (2017). Building Information Modelling (BIM) standardisation.

European Commission (2020). Building logbook state of play.

European Commission (2020). Circular economy Action Plan.

European Commission (2020). Definition of the digital building logbook Report 1 of the study on the development of a European Union framework for buildings' digital logbook.

European Commission (2020). Digital Europe. Draft Orientations for the preparation of the work. programme(s) 2021-2022.

European Commission (2017). JRC Science for Policy report. Building Information Modelling (BIM) standardisation.

European Commission (2019). JRC Science for Policy report. Digital Transformation in Transport, Construction, Energy, Government and Public Administration.

European Commission (2020). Orientations towards the first Strategic Plan implementing the research and innovation framework programme Horizon Europe.

European Commission (2020). Report 2 of the study on the development of a European Union framework for buildings' digital logbook.

European Commission (2019). Supporting digitalisation of the construction sector and SMEs, Including Building Information Modelling.

European Commission (2020). Shaping Europe's Digital Future.

European Construction Industry Federation (2020). FIEC position paper on the relationship between users and software companies/editors/service providers.

European Construction Sector Observatory (2017). Analytical Report. Human Capital in the Construction Sector.

European Construction Sector Observatory (2019). Building Information Modelling in the EU construction sector.

European Cyber Security Organisation (2019). BIM in the EU construction sector.

European Cyber Security Organisation (2019). Integrating digital innovations in the construction sector. The case of 3D Printing and Drones in construction.

European Investment Bank (2019). EIBIS Report on Digitalisation.

European Investment Bank (2019). Investment Survey 2019.

European Investment Bank (2020). Investment Survey 2020.

Future Insight Group (2019). Technical report for contract SRSS/C2019/024 - Introducing a Building Information Model (BIM)-based process for building permits in Estonia.

Germany's Federal Ministry of Transport and Digital Infrastructure (2017). Roadmap for Digital Design and Construction.

International Federation of Surveyors (2019). Best Practices 3D Cadastres.

McGraw Hill Construction (2014). The Business Value of BIM for Owners.

McKinsey (2020). The next normal in construction.

HSE (2018). Improving Health and Safety Outcomes in Construction. Making the Case for Building Information Modelling (BIM).

National BIM Council (2017). Roadmap to Digital Transition - For Ireland's Construction Industry 2018-2021.

Nawi, M.N.; Baluch, N.; Bahauddin, A.Y (2014). Impact of Fragmentation Issue in Construction Industry: An Overview.

Noardo et al. (2020). Integrating expertises and ambitions for data-driven digital building permits.

Olsson et al. (2018). Automation of Building Permission by Integration of BIM and Geospatial Data. ISPRS International Journal of GeoInformation, 7, 307.

PwC (2018). BIM Level 2 Benefits Measurement Application of PwC's BIM Level 2 Benefits Measurement Methodology to Public Sector Capital Assets.

PwC (2019). Mapping, optimizing and adjusting for the introduction of e-construction of the procedures of the Register of Buildings - Final report.

PwC (2019). The Lost Workforce: Upskilling for the Future.

RICS (2017). Global trends in data capture and management in real estate and construction.

RICS Trend Paper (2019). The use and value of commercial property data.

Sun et al. (2019). Utilizing BIM and GIS for Representation and Visualisation of 3D Cadastre.

World Economic Forum (2016). Shaping the Future of Construction. A Breakthrough in Mindset and Technology.

Annexes

Annex 1: Survey questions

Survey on Digitalisation in the construction sector

The **European Construction Sector Observatory (ECSO)** was set up in 2015 to regularly analyse and carry out comparative assessments of the construction sector in all EU countries towards these objectives. It aims to keep EU policymakers and stakeholders up to date on market conditions and policy developments.

In this context, a study on the state of play of digitalisation in the construction sector in each of the European Member States was commissioned. The work undertaken is meant to lead to a better understanding of the drivers and challenges faced by the public and private sector in this process and provide evidence-based lessons learnt and policy insights.

We would like to ask you to complete this 10 minute survey and share your feedback and insights on the digitalisation of the construction sector, which will feed into this report and enrich the debate on what the EU and its Member States could do to support such a challenging (but certainly rewarding) process.

Background questions

1. **Please indicate in what capacity you will answer the following survey**
   - Public authority
   - Construction sector company
   - Industry association
   - Academia
   - Other (open field to clarify)

2. **Please indicate what is the country which you will refer to when providing your assessment of the state of digitalisation:**
   - EU
   - Austria
   - Belgium
   - Bulgaria
   - Croatia
   - Cyprus
   - Czech Republic
   - Denmark
   - Germany
   - Greece
   - Estonia
   - Finland
   - France
   - Hungary
   - Ireland
   - Italy
   - Latvia
   - Lithuania
   - Luxembourg
   - Malta

- Netherlands
- Poland
- Portugal
- Romania
- Slovakia
- Slovenia
- Spain
- Sweden

Adoption of digital technologies by the construction sector

Definitions:

Sensors: sensor is a device, module, machine, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor.

Internet of Things: The Internet of things (IoT) describes the network of physical objects—"things"—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the Internet.

Robotics: Robotics is an interdisciplinary research area at the interface of computer science and engineering. Robotics involves design, construction, operation, and use of robots.

3D Printing: 3D printing, or additive manufacturing, is the construction of a three-dimensional object from a CAD model or a digital 3D model.

Drones: An unmanned aerial vehicle (UAV) (or uncrewed aerial vehicle, commonly known as a drone) is an aircraft without a human pilot on board.

3D Scanning: 3D scanning is the process of analyzing a real-world object or environment to collect data on its shape and possibly its appearance (e.g. colour). The collected data can then be used to construct digital 3D models.

BIM: Building information modeling (BIM) is a process supported by various tools, technologies and contracts involving the generation and management of digital representations of physical and functional characteristics of places.

Virtual and augmented reality: Virtual reality (VR) is a simulated experience that can be similar to or completely different from the real world. Augmented reality (AR) is an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory and olfactory.

Artificial intelligence: the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages.

1. **To what extent are the following technologies used in the construction sector in your country currently?**

	Not used at all	Used to a small extent	Used to a moderate extent	Used to a large extent	Very large extent
Sensors					
Internet of Things					
Robotics					
3D Printing					
Drones					
3D scanning					
BIM					
Virtual and augmented reality					
Artificial intelligence					

2. **Where possible could you add numbers (e.g. adoption rate, market development forecast, and/or links towards relevant sources of information)**

	Additional information (adoption rate, market potential, sources of information, advanced/limited use of the said technologies etc.)
Sensors	
Internet of Things	
Robotics	
3D Printing	
Drones	
3D scanning	
BIM	
Virtual and augmented reality	
Artificial intelligence	

Public policy to support digitalisation

3. **What policy or measure is in place to support BIM adoption? (Multiple choice question)**

- Binding BIM requirements in public procurement for all projects
- Binding BIM requirements in public procurement for projects of certain budget or higher
- Non-binding BIM suggestions for BIM use in public procurement
- BIM/Digital Construction Strategy
- BIM Standards and/or guidance
- National working group on BIM
- Other – please specify

4. **To what extent is the building permit system in your country digitalised?**

- There is no publicly accessible website for building permission application.
- A website is available with published information necessary to start the procedure to obtain a building or renovation permission.

- The public website offers, besides basic information, the possibility to obtain the paper form to start the building application procedure in a non-electronic way.
- There are increased electronic capabilities at the public website such as to start the procedure to obtain a building or renovation permission through an electronic form.
- The building permission can be applied, managed and validated completely electronically.
- The procedure of the building permission includes partially/fully the use of a BIM model.

Clarification:

5. To which extent does the building permit system in your country includes the use of BIM and/or GIS?
- Not used at all
- Used to a small extent
- Used to a moderate extent
- Used to a high extent
- Very high extent

6. Are there any digital building logbooks in your country?
- Yes – please provide the link(s)
- No

7. Are there any digital registries of property (cadastre) in your country?
- Yes – please provide the link(s)
- No

8. Are digital twins used in your country?
- Yes – please provide the link(s)
- No

9. How many cities have implemented digital twins – please add their names and provide link? (open text question)

10. Are there any digital construction platforms available in your country?
- Yes – please provide the link(s)
- No

11. What are the main functionalities of these platforms? (Conditional question – does not appear if respondents select yes to the previous question)
- Networking/collaboration with other companies
- Industrial data and knowledge sharing
- Establish industrial standards, common language and interoperability
- Facilitate public/private coordination
- Facilitate access to public funds in R&I and other fields
- Training and learning opportunities

12. To what extent are the digital construction platforms available in your country used by the private sector?
- Not used at all

- Used to a small extent
- Used to a moderate extent
- Used to a high extent
- Used to a very large extent

Challenges and drivers of digitalisation in the construction sector

13. To what extent are the following drivers important for the take up of digital technologies and tools in the construction sector?

	not at all	to a small extent	to a moderate extent	to a high extent	to a very large extent
EU and National Government policies and regulations (including on i) resource and energy efficiency, ii) circular economy; and iii) innovation and digitalisation)					
Market demand vis a vis i) energy efficient solutions for the construction and renovation of buildings; ii) innovative solutions					
Corporate social responsibility to help tackle climate change, and waste					
Business needs to cut costs					
Business needs to improve productivity to tackle labour					

shortages					
Business needs to remain competitive to enter third markets; and/or compete vis a vis international companies locally					
Government and business need to reduce administrative burden					
Government and business need for a better access to information and better decision making					

14. **Are there other drivers that were not included in the table above? If so, how do they affect the adoption of digital technologies in the construction sector? (open text question)**

15. **What do you think are the main challenges for increasing the use of different digital technologies and tools in the construction sector?**

	Cost of equipment and software	Lack of skilled human resource	Unclear legal framework	Lack of awareness and understanding	Lack of standards	Difficult to adapt work processes and culture	Technological readiness	Low expected return	Unavailability of equipment and software	Lack of synergies and consistency between technologies
Sensors										
Internet of Things										
3D Printing										
Drones										
3D scanning										
BIM										
Virtual and augmented reality										
Artificial intelligence										
Digital twins										

Digital construction platforms										
Digital building logbooks										
Digital registries of property (cadastre)										
Digital permits system										
GIS										
BIM requirement in public procurement										

16. **Are there other barriers that were not included in the table above? If so, how do they affect the adoption of digital technologies in the construction sector? (open text question)**

EU policy recommendations

17. **Do you see the need for an EU policy intervention to support the digitalisation of the construction sector?**

- Yes
- No – please explain

18. **What type of EU policy intervention would you think is the most relevant? (multiple choice question, conditional on Yes response to previous question)**

	Regulation	Financial support for companies to invest in digital technologies	Development of EU wide frameworks and standards technologies	Research and innovation projects relating to digital technologies in the construction sector	Awareness raising campaigns on digitalisation benefits	Support to digitalisation upskilling (training programme etc.)	Creation of demand for innovation and digitalisation through procurement and flagship initiatives (e.g. Renovation Wave)
Sensors							
Internet of Things							
3D Printing							
Drones							
3D scanning							
BIM							
Virtual and augmented reality							
Artificial intelligence							
Digital twins							
Digital construction platforms							
Digital logbooks							
Digital registries of property (cadastre)							
Digital permits system							
GIS							
BIM requirement in public procurement							

19. Are there other types of support that were not included in the table above? If so, what would they be and how would they affect the adoption of digital technologies in the construction sector? (open text question)

20. What phase of construction is the most important to achieve digitalisation of the construction ecosystem? (rank in order of importance)

Construction phase	Not Important	Slightly Important	Moderately Important	Important	Very Important
Planning and authorisation phase					
(Urban, architectural and engineering) Design phase					
Construction phase					
Operation and maintenance					
Renovation, refurbishment					
Demolition					
Recycling					

21. Are there other construction phases that were not included in the table above? If so, what would they be and how would rank them? (open text question)

22. On which technologies and tools should EU and national policies be focused on? (rank in order of importance)

Technologies and tools	Not Important	Slightly Important	Moderately Important	Important	Very Important
Sensors					
Internet of Things					
Automation					
3D Printing					
Drones					
3D scanning					
BIM					
Virtual and augmented reality					
Artificial intelligence					
Digital twins					
Digital construction platforms					
Digital logbooks					
Digital registries of property (cadastre)					
Digital permits system					
GIS					
BIM requirement in public					

procurement					

Clarification:

23.Can we contact you to follow up on your responses

- Yes – please provide your contact details
- No

Annex 2: Interview questionnaire

As part of this study, we developed two interview questionnaires, one for public sector representative, and another one for private sector's.

Public sector representative questionnaire

Introduction	Please introduce yourself shortly • What is your experience with digitalisation in the construction sector?
Adoption private	Our report focuses on the following technologies: Sensors, Internet of Things, Robotics, 3D Printing, Drones, 3D scanning, BIM, Virtual and augmented reality, and Artificial intelligence. • Which ones you think are the most spread? Why? • What are the ones you think will spread most in the near future? • In which MS or regions are these technologies mostly spread?
Adoption public	Our report focuses on the following technologies: BIM, digital building permit system (using BIM and/or GIS), digital building logbooks, digital registries of property (cadastre), digital twins. • Which ones you think are the most spread? Why? • What are the ones you think will spread most in the near future? • In which MS or regions are these technologies mostly spread?
Trends in the value chains	• Do you feel that the public sector as a client is demanding more and more the use of digital technologies for construction related projects? • Would you consider that most public sector officer are aware of digitalisation benefits, and educated in terms of how to use them?
Barriers	• What are the main barriers to the digitalisation of the construction sector? • Are some more relevant for specific digital technologies
Drivers	• What are the main drivers to the digitalisation of the construction sector? • Are some more relevant for specific digital technologies
Support to digitalisation	• What were the most and the least relevant government initiatives supporting digitalisation in the construction sector that you have witnessed so far (regulations, financial incentives, national digital platforms etc.)? Why?
Recommendations	• What would recommend the EC should do to support the digitalisation of the construction sector? • What actors in the construction value chains should the EU intervention target to have maximum impact?
Conclusion	• Would you recommend any reports or study your organisations (or another one) has published on the topic?

Private sector representative questionnaire

Introduction	Please introduce yourself shortly • What is your experience with digitalisation in the construction sector?
Adoption private	Our report focuses on the following technologies: Sensors, Internet of Things, Robotics, 3D Printing, Drones, 3D scanning, BIM, Virtual and augmented reality, and Artificial intelligence. • Which ones you think are the most spread? Why? • What are the ones you think will spread most in the near future? • In which MS or regions are these technologies mostly spread?
Trends in the construction value chains	Based on your experience in interacting with other construction firms down the supply chains • what are the main trends in terms of attitude/adoption of digital technologies that we need to take into account for the report? Why is that? What about your interaction with clients from the public and private sector: • have you seen a change in terms of their demands for digital technologies? Do you consider that clients are widely aware of the benefits of, and use digital technologies?
Barriers	• What are the main barriers to the digitalisation of the construction sector? • Are some more relevant for specific digital technologies
Drivers	• What are the main drivers to the digitalisation of the construction sector? • Are some more relevant for specific digital technologies
Support to digitalisation	• What were the most and the least relevant government initiatives supporting digitalisation in the construction sector that you have witnessed so far (regulations,

	financial incentives, national digital platforms etc.)? Why?
Recommendations	• What would recommend the EC should do to support the digitalisation of the construction sector? • What actors in the construction value chains should the EU intervention target to have maximum impact?
Conclusion	• Would you recommend any reports or study your organisations (or another one) has published on the topic?

Annex 3: Digital construction policies in the EU-27

Type of Digital Construction Policy							
Countries	Strategies/Policies	Horizontal Policy/Strategy – does not comprise construction	Horizontal Policy/Strategy – comprises construction	Vertical Policy/Strategy – targets the construction sector	Comprehensiveness		
					Strategy	Action Plan	Financial instruments
Austria	• Digitisation in the construction industry Research and technology development in Austria • Energy Innovation Austria		√		√	√	√
Belgium	• Digital Belgium; • Vlaanderen Radicaal Digitaal II • Digital Wallonia.be	√			√	√	√
Bulgaria	• DIGITAL TRANSFORMATION OF BULGARIA FOR THE PERIOD 2020-2030; • RESTART 2016-2020		√		√	√	√
Croatia	• e-Croatia		√		√	√	
Cyprus	• RESTART 2016-2020		√		√	√	√
Czech Republic	• Innovation Strategy of the Czech Republic 2019 – 2030 • Ministry of Industry and Trade – on BIM; • Digital Czech Republic 2019; • The concept of implementing the BIM method in the Czech Republic - BIM Koncepce 2022		√		√	√	√
Denmark	• Strategy for Denmark's Digital Growth		√		√	√	√

Estonia	• Government of the Republic of Estonia DIGITAL AGENDA 2020 FOR ESTONIA • E-ehituse platvormi visioon			√	√	√	
Finland	• The Digital Future of Construction - Interview with the Minister of the Environment, Energy, and Housing of the Finnish government • 'Long-term strategy for mobilising investment in the renovation of buildings', • ERA17 Action Plan – For an Energy-Smart Built Environment 2017'			√	√	√	√
France	• PlanBIM 2022			√	√	√	√
Germany	• Roadmap for digital design and construction			√	√	√	
Greece	• Ministry of Digital Policy, Telecommunications and Media General Secretariat for Digital Policy (2016), NATIONAL DIGITAL POLICY 2016-2021 • Research and Innovation Strategies for Smart Specialisation (RIS3) • TEE (2020), Digital Construction and BIM in Greece			√	√	√	√
Hungary	• National Digitalisation Strategy	√			√	√	√
Ireland	• Road Map to Digital Transition for Ireland's Construction Industry (2018-2021) • National BIM Council			√	√	√	√
Italy	• l'Agenzia per l'Italia Digitale e il Dipartimento per la Trasformazione Digitale. (2020), Piano Triennale per l'informatica nella Pubblica Amministrazione; • "Repubblica Digitale";	√			√	√	√

Latvia	• "Road map for BIM implementation in construction sector of Latvia" (under development)		*[531]				
Lithuania	• National BIM strategy • On Development of BIM Methodology and Digital Construction in Lithuania over the Period 2014-2020; • Public institution "Skaitmenine statyba" ("Digital Construction"); • Lithuanian Industry Digitisation Roadmap for 2019-2030			√	√	√	√
Luxembourg	• Digital Luxembourg, building information modeling (bim) • CRTI-B • Digitabuilding.lu			√	√	√	√
Malta	• Digital Malta Strategy 2014-2020	√			√	√	√
Netherlands	• Dutch Digitalisation Strategy;	√					
Poland	• Poland Digitalisation Strategy	√					
Portugal	• Industria 4.0;	√			√	√	√
Romania	• National Strategy on the Digital Agenda for Romania 2020	√					
Slovakia	• 2030 Digital Transformation Strategy for Slovakia: Strategy for transformation of Slovakia into a successful digital country;	√			√	√	√
Slovenia	• Action Plan for the Introduction of Digitisation in the Field of the Built Environment in the Republic of Slovenia (not published yet)		*				

[531] Latvia's strategy is currently under development.

Spain	• EspaNa diGital 2025; • Interministerial Commission for the incorporation of the BIM methodology in public procurement; • Es.BIM;			√	√	√	
Sweden	• Smart Built Environment			√	√	√	√

Annex 4: BIM related strategies and standards

The Table below provides an overview of BIM support measures based on a desk research[532] and the survey results.

Type of BIM support measures			
Countries	BIM/Digital Construction Strategy	BIM Standards and/or guidance	National working group on BIM
Austria		• Standards: ÖNORM A 6241-1: 2015 07 01 (en)	• Austrian Standards Institute (en)
Belgium		• Guidance: Building Information Modelling – Belgian Guide for the Construction Industry	• Le Centre scientifique et technique de la construction (CSTC) fr • Wetenschappelijk en Technisch Centrum voor het Bouwbedrijf (WTCB) nl
Bulgaria	• Upcoming strategy		
Croatia			• HR BIM Task Group under the Ministry of Physical Planning, Construction and State Assets
Cyprus			
Czech Republic	• BIM Implementation Strategy in the Czech Republic • The Government approved an update of the schedule of the Concept for the Implementation of the BIM Method in the Czech Republic and took note of the information on its implementation		• Ministry of Industry and Trade (MIT) (en) • Czech Standardisation Agency (CAS) (en) • CzBIM (cz)

532 The desk research includes : the EU BIM Observatory (2018); Bakogiannis et al. (2020); Karlsson et al. (2018). https://www.cloudalize.com/blog/bim-landscape-europe/ for column 2 and 3

Denmark		• Guidance: bips CAD Manual	• Danish Building and Property Agency (en)
Estonia	• E-construction platform	• EVS 928:2016 (en) • Public Clients Common BIM Requirements	• Ministry of Economic Affairs and Communications (MKM) (en) Estonian Centre for Standardisation (en) • Public Clients BIM Task Group
Finland		• Standards SFS-EN ISO 19650-1:2019 (en) • SFS-EN ISO 19650-2:2019 (en) • Guidance: COBIM - Common BIM Requirement	• Senaatti (fi)
France	• PTNB-Plan Transition Numérique dans le Bâtiment • Plan BIM 2022 • National project for infrastructures supported by the ministry: MINnD	• NF EN ISO 19650-1 (fr) • NF EN ISO 19650-2 (fr)	• Ministry of Housing and Territorial Equality (fr)
Germany	• The roadmap for digital design and construction (Stufenplan Digitales Planen und Bauen 4.0)	• Deutsches Institut für Normung e.V. (DIN) (en) • DIN SPEC 91400 (en) • Guidance: BIM-Leitfaden für Deutschland	• The Federal Ministry of Transport and Digital Infrastructure (BMVI) (en) • planen-bauen 4.0: official-BIM steering group established by the BMVI (de)
Greece	• Upcoming strategy	• ΕΛΟΤ/ΤΕ 22 «Πληροφόρηση – Τεκμηρίωση» (el)	• Technical Chamber of Greece (TEE) (en)
Hungary		• Hungarian Standards Board (en)	
Ireland	• The National BIM Council and its Construction 2020 Strategies	• National Standards Authority of Ireland (NSAI) (en)	• National BIM Council (en) • Entreprise Ireland (en)
Italy	• The Infrastructure and Transport Ministry Decree	• Ente Nazionale Italiano di Unificazione (it)	• Institute for BIM Italy (it)

	(560/2017) Legislative decree		
Latvia	• The BIM Roadmap		• LatBIM (lv)
Lithuania	• National BIM implementation strategy in Lithuanian construction sector	• Lithuanian Standards Board - National Standards Body • Technical Committee 88 – Building Information Modelling (BIM)	• Ministry of Environment of the Republic of Lithuania
Luxembourg		• ILNAS-EN ISO 19650 (en) • Guide d'application BIM	• Le Centre de Ressources des techniques de de l'innovation pour le batiment (CRTI.B) (fr) • Digital BIM (fr)
Malta			
Netherlands		• RVB BIM Standard v1.0.1 (en)	• Rijksvastgoedbedrijf (RVB) (en)
Poland		• Polski Komitet Normalizacyjny (pl)	• Ministry of Investment and Development (pl)
Portugal		• CEN/TC 442	
Romania		• SR EN ISO 19650-1: 2019 • SR EN ISO 19650-2: 2019	• Official Communication from the Romanian Standardisation Agency (ASRO) (ro)
Slovakia		• STN EN ISO 16739 (en) • STN EN ISO 29481-2 (en) • STN EN ISO 12006-3 (en)	• No national body. • Faculty of Civil Engineering of the Slovak University of Technology (sk)
Slovenia		• Slovenian Institute for Standardisation (SIST) (sl)	
Spain	• The BIM National Strategy esBIM	• PNE-EN ISO 19650-1 (en)	• Es.BIM Commission (en) • Interministerial Commission for the adoption of the BIM methodology in public procurement (CBIM)
Sweden		• Swedish Institute for Standards (SIS) en	

Annex 5: Digital construction platforms in the EU-27

Countries	Digital Construction Platform	Type of platform
Austria	Yes	• Austrian Construction Technology Platform (ACTP) Description: The ACTP aims to establish a national network for research and development in the field fo construction, focusing on knowledge exchange within the Austrian construction sector and between European and Austrian construction sector.
Belgium	Yes	• BIM Portal Belgium Description: an awareness and information portal about BIM. The BIM Portal aims to become the Belgian reference portal site for BIM and other digital applications to meet the construction world's needs. The objective is to provide professionals with easy access to high-quality and relevant information and offer them the opportunity to share information. It is an initiative of the Technical Committee BIM & ICT of the BBRI (the Scientific and Technical Centre for the Construction Company). • Digital Construction Belgium Description: Collaboration platforms like Bricsys, or specific focus like LetsBuild, project-based sites such as Lantis. • ADEB Digital Board Description: an association aimed at major works contractors. It positions itself as the representative and spokesperson of the major construction companies in Belgium. The ADEB is part of the Construction Confederation. • Antwerp smart zone Description: City-level platform using inter-connected smart cameras and sensors in order to find solutions for secure streets and to make more efficient use of light in a dark square.
Bulgaria	Not found	
Croatia	Terminated	• Croatian Competitiveness Cluster for the Construction Industry (Hrvatski klaster konkurentnosti građevinske industrije - HKKGI) Description: an industry platform for networking and cooperation between entities in the construction sector, scientific research and the public sector, aims to improve the competitiveness in the Croatian construction sector. The HKKGI seeks to strengthen cooperation with other partners on joint EU projects, carry out development studies and identify important new markets and opportunities for cooperation, as well as bring about the internationalisation

		of cluster members through meetings with foreign business partners, participation in international conferences, fairs and exhibitions, and providing information and consulting to cluster members on new business opportunities.
Cyprus	Not found	
Czech Republic	Yes	• BIM Strategy Division Description: an expert governmental platform for standardisation and methodological support for the digitalisation of construction sector. • CZBIM Description: an independent platform for the popularisation, promotion, standardisation and development of BIM in the Czech Republic. The association defends and promotes the interests not only of its members, but of the entire private sector, ensures that the implementation of BIM in the Czech Republic is transparent and that experience and needs from real practice are considered.
Denmark	Yes	• Molio Description: a platform which collects, processes and disseminates knowledge through the development of digital tools, standards, courses and textbooks that help everyone in construction to an easier and more competitive everyday life.
Estonia	Yes	• eeithus Description: a platform whose goal is to ensure continuous and unhindered access to public construction information and to enable authorised persons to view, enter and continuously change and supplement specific information. • visiidid.ee Description: the platform aims wider exports of Estonian enterprises and increase the foreign investments.
Finland	Yes	• The MESTA.net Description: a platform addressed to young people in order to provide them information on careers in construction, real estate and design, as well as on all available training courses in the sector. • EconomisE Platform Description: a platform to coordinate multi-stakeholder to achieve accelerated energy decarbonisation and resilience in Finnish buildings. • Kirahub Description: a transparent platform for intra-industry and cross-sectoral debate on human, ecological and economic sustainability, to increase the scale of discussions, to involve polyphony, to facilitate the refinement and commercialisation of ideas and to bring lessons internationally to the industry. • Kiradigi

		Description: a platform to boost the digitalisation of the built environment and construction sector! The Government's key project involves ministries, municipalities and the KIRA forum. The aim is to create an open and interoperable information management ecosystem for the built environment..
France	Yes	• National construction platform Description: a platform which provide information about construction employment. • KROQI Description: a public and free collaborative work platform for all construction professionals. It offers a range of services aimed at making the use of BIM more accessible, particularly for VSE/SMEs in the sector. KROQI is an exchange and collaboration tool for companies in the construction industry that allows them to share and manage digital BIM files and models in a secure manner, to view and check digital models without having to use complex tools or paying services, to access various business services to optimise professional activity, integrated into the BIM design and collaboration processes, and to collaborate easily with collaborators, partners or clients (threads, etc.). of discussions, videoconferencing, shared management of agendas, monitoring of tasks, etc.).
Germany	Yes	• "Deutschland baut!" Description: a common platform for all companies in the construction sector and a network to facilitate cooperation among industry stakeholders. Description: the national centre for the digitisation of the building industry. It is the federal government's central public contact point for information and activities relating to Building Information Modelling (BIM). The products, open standards and concepts are made available to both public construction and the entire construction value chain.
Greece	Yes	• Exportgate Description: online portal which aim to provide an integrated singular platform for networking, trade development and industry analysis support. • BIM Design Hub Description: BIM Design Hub is an Autodesk Authorised Training Centre focused both on the integration of BIM in the design and construction process and its implementation through Autodesk software technology, aiming to meet the latest construction industry demands as well as certification requirements. • Pedmede Panhellenic Association of Engineers Contractors of Public Works Description: a platform whose objective is to the promote BIM and as well as the digitalisation in the sector.
Hungary	Yes	• Hungarian National Trading House (HNTH) Description: an online training platform for SMEs on how to do business in markets outside the EU. • Added Value Economics Research and Development Institute Association

		Description: a platform which caters for the specific needs and gaps of enterprises in its region (nationally and globally), particularly SMEs, manufacturing companies and stakeholders nationwide. It supports the manufacturing industry in all economic sectors, including construction.
Ireland	Yes	• CitA Description: a research project in Dublin Institute of Technology in association with the Waterford Institute of Technology in May 2001, with the vision of harnessing the potential of ICT in the Irish construction industry. CitA transmits the latest information on technology trends through monthly events and annual conferences with experts in key areas whilst providing networking opportunities with peers. • CitA BIM Education Forum Description: CitA is a platform which aims to develop the conversation around BIM in Education in a consistent and joined-up way, and the Forum aims to provide an opportunity for them to express their views/opinions, and find out what other organisations are doing with regards to education in BIM Pilot Projects. • Construction 4.0 Committee Description: The primary focus for the Construction 4.0 Committee in 2020 will be to support the establishment of the Build: Digital Project, to work with Enterprise Ireland to develop a Research, Development & Innovation Technology Centre for the construction industry, and to develop a coherent policy with respect to modular, modern methods of construction (MMOC) and off-site fabrication.
Italy	Terminated	• INNOVance Description: is a project supported through public national plan "Industria 2015" whose objective is to implement on a Data-Base framework in order to enhance collaboration between all the stakeholder of construction industry. The web-based platform is still online, but latest update date back to 2015. This project was an essential experience for the outlining of new construction platform (currently under discussion with the Ministry of Economic Development).
Latvia	Yes	• Startup Ecosystem Forum Description: a forum which connects Latvian start-ups with academic sectors, non-governmental organisations as well as large and state-owned companies on a single platform. • OROCON start-up Description: a management system for construction companies which acts as a cooperation platform that simplifies the burden of supervising several projects at a time. • Construction Information System (BIS) Description: an online platform providing access to all construction documentation and relevant information. • **Association for Construction Industry Digitalisation** Description: improve the construction process and the efficiency of the employees, the structure of the work

		organisation and the whole area. The objectives of the association are education and consulting in public and private construction in the field of digitalisation, development and implementation of construction tools and technologies such as BIM in the construction sector in Latvia and Europe, improvement of performance indicators for construction companies, participation in European and Latvian construction legislation, and participation in the development of construction information systems.
Lithuania	Yes	• Ministry of Environment of the Republic of Lithuania • www.statyba40.lt - a website for all Government led digitalisation initiatives of Lithuanian construction sector. • National Industry Digitalisation Platform 'Pramonė 4.0' Description: a platform supporting the Lithuania economy's digital transformation. • National Platform of Qualifications of Construction Sector Workforce Description: a national platform which aimed at developing and recognising professional competences and skills of the building workforce. • Public institution Skaitmeninė statyba Description: a platform that joins associations of Lithuanian construction sector and coordinates the digitalisation process of Lithuanian construction.
Luxembourg	Yes	• Resource Centre for Technologies and Innovation in Construction Description: a platform which aim at gathering the main players in the sector and one of the objectives of which is to develop a BIM guide. • Luxembourg for Business and Innovation (LfBI) Description: a networking platform for exporters, offering advice and information. • Luxembourg Digital Innovation Hub Description: the platform supports the development of the data-driven economy in Luxembourg. It helps companies find the right experts, advisors and IT solutions providers here or in other European countries who can help them define and succeed with their digital transformation. • Digital Building Luxembourg Description: a platform that organises workshops around BIM, each focused on a specific sector profession. The objective of the workshops is to inform about existing technical solutions and their possibilities, to correct the erroneous images that everyone may have about BIM, to show through user feedback that BIM can be beneficial for the different actors of a construction project, sector by sector, and to create exchanges between people of the same discipline to share their BIM experiences.
Malta	Not found	

Netherlands	Yes	• Platform for Accelerating the Circular Economy (PACE) Description: a platform specialised in learning from the experiences of other developed economies to better transition itself into a waste less economy. • "Madaster Foundation" Description: a platform which improves the construction waste management and develops a "material passport". bouwopleiders Description: a platform which provide graduates information and advice on the training offer in the construction sector. • 'NL International Business' Description: a platform which aim at supporting "first movers" in international markets.
Poland	Yes	• Polish Construction Technology Platform (PPTB) Description: a platform which brings together 56 construction stakeholders to exchange technical and scientific information. • BIM Klaster Description: Association of pro-innovative and highly specialised micro, small, medium and large enterprises from the entire territory of Poland, which are active in construction industry and in ICT, as well as of business and research & development public institutions which support the creativity and innovative drive in the Polish economy.
Portugal	Yes	• Sustainable Construction Platform Description: a platform linking businesses, R&D centres, as well as municipalities. • Portuguese Technological construction platform (PTPC) Description: a platform which promotes initiatives in research and innovation in the construction sector. • ADENE Academy platform Description: a platform which offers training modules for construction professionals focusing on energy efficiency skills.
Romania	Yes	• BIMTECH Description: a multidisciplinary team of specialists consisting of academics, architects, engineers, lawyers and entrepreneurs. The members of the Association want to associate in order to research, develop and implement applicable technologies within a platform for design, management, execution and operation of the built environment.
Slovakia	Yes	• BIM association Slovakia Description: a non-profit organisation focused on the application of BIM (Building Information Modelling) in a professional practice on the level of all stakeholders in the project and construction process for the whole duration of the life cycle of the construction. The main role of the association is the promotion, popularisation and development

		of the possibilities and the application of this technology within Slovakia.
Slovenia	Yes	• The BIM Association Slovenia (siBIM) Description: a voluntary, independent and non-profit organisation that connects engineers and engineering enthusiasts, who participate or would like to participate in building information modelling (BIM) in the built-environment industry. Its purpose is to provide networking and training, professional development, social gatherings and exchanges of experience.
Spain	Yes	• Be-Spoke Capital Description: a platform which provides support to Spanish SMEs and mid-caps with long-term financing opportunities. • Es.BIM Description: a group open to all agents involved (administrators, engineers, builders, universities, professionals, etc.) whose main mission is the implementation of BIM in Spain. It is a multidisciplinary group, organised by subjects and in which a chairman will act as the driving force in the works.
Sweden	Yes	• Platform for artificial intelligence Description: a platform whose objective is to develop training initiatives and related activities in education and research in line with the development of artificial intelligence. • BIM Alliance Sweden • Description: a non-profit organisation working for a better built environment by maintaining seamless information flows in the design, construction and maintenance processes.

Annex 6: Relevance of challenges by country

Table 7: Percentage of respondents to the survey in each MS who consider the challenge as important[533]

	Cost of equipment and software	Lack of skilled human resource	Unclear legal framework	Lack of awareness and understanding	Lack of standards	Difficult to adapt work processes and culture	Technological readiness	Low expected return	Unavailability of equipment and software	Lack of synergies and consistency between technologies
Austria	20%	47%	53%	73%	40%	33%	47%	0%	13%	0%
Belgium	41%	66%	30%	64%	20%	48%	34%	27%	27%	30%
Bulgaria	100%	90%	90%	60%	100%	80%	80%	50%	60%	70%
Croatia	39%	49%	27%	50%	31%	44%	33%	28%	14%	24%
Cyprus	25%	0%	0%	0%	0%	50%	25%	50%	0%	0%
Czech Republic	0%	100%	100%	100%	100%	100%	33%	0%	33%	100%
Denmark	23%	26%	16%	42%	26%	16%	29%	19%	3%	23%
Germany	32%	50%	12%	26%	50%	18%	18%	12%	18%	62%
Greece	42%	65%	40%	21%	23%	19%	13%	4%	13%	17%
Estonia	29%	52%	31%	34%	46%	22%	18%	15%	2%	23%
Finland	0%	27%	0%	62%	12%	15%	31%	4%	4%	15%
France	100%	0%	0%	0%	0%	100%	0%	100%	0%	100%
Hungary	50%	0%	0%	0%	0%	0%	50%	50%	0%	0%
Ireland	44%	45%	12%	51%	14%	30%	29%	31%	19%	8%
Italy	43%	36%	32%	32%	25%	43%	11%	25%	11%	25%
Latvia	25%	32%	39%	57%	29%	25%	18%	18%	0%	25%
Lithuania	75%	75%	0%	25%	50%	50%	50%	0%	25%	25%
Luxembourg	0%	100%	40%	80%	20%	40%	13%	0%	7%	20%
Malta	50%	50%	50%	0%	0%	0%	0%	0%	0%	50%
Netherlands	25%	42%	4%	42%	21%	75%	13%	4%	25%	4%
Portugal	9%	23%	77%	64%	86%	23%	64%	5%	9%	9%
Romania	55%	18%	9%	36%	9%	27%	27%	0%	9%	9%
Spain	20%	20%	20%	60%	40%	20%	0%	60%	0%	0%
Sweden	20%	24%	39%	55%	39%	80%	29%	20%	14%	20%
EU weighted total	28%	43%	25%	45%	32%	31%	22%	16%	8%	21%

Source: ECSO survey

533 In the survey, multiple answers were possible, hence the total per row is >100%.